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Heritability of Initiation and Duration of Breastfeeding Behavior

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Breastfeeding is considered the best and most natural way of feeding infants during the first months of life. Breastfeeding has multiple short- and long-term benefits for the health of the mother and babies, and from an evolutionist standpoint, it would be a behavior worth preserving throughout time. The aim of the present study was to explore the relative influence of genetic and environmental factors in this behavior. Three hundred and ninety pairs of adult female twins provided information about whether they breastfed their children and for how long. Three variables were analyzed: initiation and duration for the first baby, and mean duration for the complete offspring. Polychoric correlations were consistently higher for monozygotic twins, supporting a role for genetic factors (0.49 vs. 0.22 for initiation; 0.44 vs. 0.22 for duration in the first newborn; and 0.52 vs. 0.31 for duration on average). Model-fitting analyses found that in the best-fitting model, variance was explained by additive genetic and non-shared environmental factors, with estimated heritabilities ranging from 0.39 to 0.52 in the measures studied. The rest of the variance would be due to unique environmental factors. We conclude that genetic factors have a significant impact on the complex behavior of breastfeeding.

Keywords: breastfeeding, heritability, twin study

Babies who are breastfed are generally healthier and achieve optimal growth and development compared with those who are fed with formula milk (UNICEF et al., 2010). Human milk feeding decreases the incidence and/or severity of a wide range of infectious diseases. Some studies suggest that breastfeeding (BF) is protective against sudden infant death syndrome in the first year of life (Hauck et al., 2011). Children and adults who were breastfed show decreased incidence of diabetes mellitus, overweight and obesity, hypercholesterolemia, and asthma. BF has been associated with slightly enhanced performance on tests of cognitive development (Hanson et al., 2009). Additionally, important health benefits of BF and lactation are also described for mothers. The benefits include decreased postpartum bleeding and more rapid uterine involution attributable to increased concentrations of oxytocin, earlier return to pre-pregnancy weight, decreased risk of breast cancer, decreased risk of ovarian cancer, and possibly decreased risk of hip fractures and osteoporosis in the post-menopausal period (Gartner et al., 2005). Moreover, BF not only benefits mothers and infants but also society by providing an effective mean of promoting health and reducing sanitary expenses (Solé, 2005).

Infant requirements for survival are universal: adequate nutrition and hygiene, enough sleep, and fulfillment of basic emotional needs (Schön & Silvén, 2007). As a part of the reproduction process, BF is at the core of these requirements. It is the tool that nature provided for feeding newborns, and it is a fundamental component of maternal behavior for all mammals, including humans. Additionally, BF favors warmth and early bonding between mother and infant. Bonding is considered an adaptation that has evolved presumably to protect newborns while they continue to develop after birth (Plomin et al., 2008), and it is likely to play a role in the development of optimal parental care behavior (World Health Organization Regional Office for Europe, 2000). BF also has stress-relieving effects on the

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mother (Bai et al., 2010) and it provides analgesia to infants (Gartner et al., 2005).

Natural selection favors those organisms which are competent in reproduction and those who take care of their breeding properly (Carlson, 2007). Accordingly, BF represents a behavior worth preserving throughout time and appropriate mechanisms to sustain it in adult breeders should have been developed. What is more, evolutionary mechanisms favoring BF could also be present in the infant. Thus, in a study on odor preferences, 2-week-old newborns who had never been breastfed were found to exhibit an apparently inborn preference for the breast odor of a lactating, unfamiliar woman, over the scent of their familiar formula (Schön & Silvén, 2007).

Initiation and maintenance of BF are strongly related to physiological events that take place in the mother's body. Pregnancy and lactation result in a number of physiological adjustments that are largely mediated by the hormonal milieu and result in general metabolic adaptations as well as structural and functional changes specific to the mammary gland (Heinig & Dewey, 1997). Breast development is influenced by a number of hormones including oestrogens, progesterone, prolactin, and human placental lactogen. Copious milk production normally occurs at 2–4 days postpartum and is not dependent on infant suckling. However, maintenance of milk production depends on suckling and milk removal. Infant suckling stimulates the release of prolactin, which in turn stimulates milk production and secretion. When suckling occurs, oxytocin is released into the circulation and causes the ejection of milk (Heinig & Dewey, 1997). Additionally, oxytocin appears to be related to other aspects related to the establishment of maternal bonding (Lee et al., 2009).

As a global public health recommendation, infants should be exclusively breastfed for the first 6 months of life to achieve optimal growth, development, and health (World Health Organization & UNICEF, 2003). In spite of that, BF rates show considerable variation within and between human societies. UNICEF estimates that 37% of children all over the world are exclusively breastfed up to 5 months (UNICEF, 2012). In the United States, 44.3% of children are partially or exclusively breastfed at 6 months (CDC, 2008). In Europe, the rates range from 96.7% of infants exclusively or partially breastfed for 6 months in Hungary to 35% in Lithuania in 2009 (World Health Organization Regional Office for Europe, 2011). In Africa, 34% of children are breastfed for up to 5 months, according to the statistics of UNICEF, from 2003 to 2008 (UNICEF, 2012).

These variations have been explained in the research literature as the effects of different factors affecting the decisions of the mothers about initiation and maintenance of BF. Factors that have been reported could be classified as biological (e.g., breast pain, soreness, or milk production; Almqvist-Tangen et al., 2012), demographic (e.g., socioeconomic status, educational levels, marital status, or age; Barona-Vilar et al., 2009; Kools et al., 2005, 2006; Scott et al., 1999; Taveras et al., 2003), psychological (e.g., personality traits, motivation, self-confidence, or maternal identity; Cooke et al., 2007; Eksioglu & Ceber, 2011; Wagner et al., 2006), and social (e.g., attitudes, or social norms; Kools et al., 2005). What is more, in the last century, BF rates have changed across time with several societal events such as the promotion and increasing availability of formula milk, migrations from rural to industrialized areas, increasing access of women to education, changes in family structure, the incorporation of mothers into the labor market, progressive increase of partners' involvement in the care of the baby, regulation of maternity leave, and an increasing number of health-promoting programs or the 'return to the nature' movement (Colodro-Conde et al., 2011; Dennis, 2002; Vahlquist, 1981).

The public health relevance of this behavior has led to an increasing interest about the causes of initiation and continuation of BF, the implications of this behavior, and the ways to promote it. As illustrated above, BF is a complex behavior where biological, psychological, and social factors are involved. Given the evolutionary significance of the initiation and maintenance of BF among the mothers of our species, and the strong physiological implications on its development, it appears that the implication of genetic factors on this behavior is granted. However, to the best of our knowledge, information concerning the heritability of natural BF has not been reported. Our objective is to fill in this gap by analyzing the role of genetic and environmental factors on the initiation and maintenance of BF, in a sample of adult female twins.

Materials and Methods

Subjects and Measures

A population-based sample of adult female twins registered by the Murcia Twin Register (MTR; Ordoñana et al., 2006) provided data for this study. The MTR reference population comprises all twin pairs who were born between 1940 and 1966 in the region. The MTR has been approved by the Murcia University Ethical Committee and it follows national regulations regarding personal data protection. All applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research.

The sample selected for this study comprised 390 pairs of twins where both members had been mothers: 202 were monozygotic (MZ) pairs and 188 were dizygotic (DZ) pairs. Mean age of the selected participants was 52.97 (*SD* 7.44; range 43–69). Zygosity was determined by questionnaire and DNA testing.

The data analyzed in this report were collected in 2007 and 2009, by telephone and personal interview, respectively. Women were asked about different aspects of their reproductive history, including initiation and duration of lactation periods for each of their children.

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Data were retrospective and based on self-report. Data from the first wave of collection were used as the reference set. Data from those women who were interviewed for the first time during the second wave were incorporated to the data set. Given that the reported behavior had taken place long ago, we assumed that no differences should be expected according to the moment of data collection (2007 vs. 2009) and both were treated as indistinguishable.

Information collected included whether they had breastfed any of their children and the duration, in months, of BF to each child. We made no difference between full and partial BF. Main variables for the analysis were: (1) initiation of BF in the firstborn child (Yes/No); (2) duration of BF for the firstborn child; and (3) mean duration of BF to all the children. Given the skewness of data distribution, variables related to BF duration were categorized in three intervals: 3 months or less, from 3 to 6 months, and more than 6 months.

Data Analyses

The data were analyzed using structural equation modeling (SEM), which allows one to test specific theoretical models in a multiple group approach. We applied the classical twin design (Falconer, 1989; Plomin et al., 2008) to estimate the contribution of genetic and environmental factors to population variation in BF behavior, using the statistical software package OpenMx. We modeled additive genetic factors (A), common environmental factors (C), and unique environmental factors (E). MZ twins share 100% of their segregating genes, and DZ twins share, on average, 50%. If MZ twins resemble each other significantly more than DZ twins, that is an indication of genetic effects on individual differences in a given trait. Similarly, if DZ twins resemble each other more than half the resemblance of MZ twins, that is an indication of shared environmental effects. Shared environmental effects are those shared by the siblings reared in the same family, whereas non-shared or unique environmental factors are those not shared by siblings reared in the same family. The distinction between these two environmental components is purely statistic, and a given environmental factor may entail both kinds of variation at different proportions.

The categorical variables were analyzed using a liability threshold model. In order to apply variance component genetic models to categorical twin data, it is assumed that the categories reflect an imprecise measurement of an underlying normal distribution of liability, which would have one or more thresholds to discriminate between the categories (Rijsdijk & Sham, 2002). This liability may be influenced by genetic and environmental factors and is normally distributed with a mean value of zero and a variance of one. Twins' similarity can be estimated by the correlation for the liability scale, called a polychoric correlation.

To be able to use all data from complete and incomplete pairs, full information maximum likelihood estimation with raw data was used. In this method, twice the negative log likelihood (-2LL) of the data for each family is calculated, and parameters are estimated so that the likelihood of the raw data is maximized. Means, variances, and twin correlations were estimated in a saturated model. Nested models were compared with likelihood ratio tests, which are obtained by subtracting -2LL for a restricted nested model from that for a less restricted model, $\chi^2 = (\text{-2LL}_0)-(\text{-2LL}_1)$. The resulting test statistic has a χ^2-distribution with degrees of freedom (*df*) equal to the difference in *df* between the two models. When the fit of a more restrictive (nested) model differs significantly from that of the less restrictive, it implies that the restriction imposed in the nested model does not hold for the available data. The best-fitting model was chosen in each case by deducting the residual deviance of the compared models and by comparing Akaike's information criterion (AIC).

Results

Descriptive Results and Twin Correlations

Women who participated in this study were 52.97 years old on average, as reported before, but they were mothers for the first time when they were 24.29 (*SD* 4.69; range 14–47). The mean number of children they had was 2.54 (*SD* 1.14; range 1–10).

A total of 680 women (87.2%) had breastfed at least one of their children. The average of BF duration to all children was 4.8 months (*SD* 4.52; range 0–36). Nearly half (44.5%) and 18.7% of the women had breastfed for more than 3 and 6 months on average, respectively. Six hundred and twenty-nine (80.6%) women breastfed their firstborn child. The mean duration in this case was 4.79 months (*SD* 5.1, range 0–36). Four out of ten (40.3%) had breastfed their firstborn for more than 3 months and 17.9/% for more than 6 months.

Estimates of the twin correlations for the three outcome variables are shown in Table 1. As expected, MZ correlations were consistently higher. The estimates of the MZ and DZ twin correlations suggest the presence of additive genetic effects for the studied variables. Additionally, in the case of BF initiation for the first newborn, MZ twin correlations were higher than twice the DZ twin correlations; hence, the presence of non-additive genetic effects was considered.

Genetic Modeling

Table 2 shows the fit of the submodels for the outcome variables: initiation of BF in the firstborn child, and durations of BF for the firstborn and in average to all children. Nested models were compared with the full model (ACE/ADE). The full genetic models showed a good fit as compared with the saturated models ($p > .05$). The best fit was observed in all cases for models with the additive genetic component in comparison with the other models. This shows the influence of additive genetic factors in the studied variables. The AE submodel provided a satisfactory fit to the data in all

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TABLE 1

Polychoric Twin Correlations with 95% confidence intervals (CI)

	r_{MZ} ($n = 202$)	r_{DZ} ($n = 188$)
Having breastfed the firstborn child	0.50 (0.26, 0.69)	0.22 (−0.10, 0.51)
Firstborn child: BF <3, 3–6, >6 months	0.44 (0.27, 0.59)	0.22 (0.01, 0.42)
Average of all children: BF <3, 3–6, >6 months	0.52 (0.37, 0.65)	0.31 (0.12, 0.49)

Note: DZ = dizygotic; MZ = monozygotic.

TABLE 2

Model-Fitting Results for Univariate Models of Initiation and Duration of Breastfeeding

		Goodness-of-fit index						Parameter estimates		
Model	Description	−2LL	*df*	AIC	$\Delta\chi^2$	Δdf	*p*	A	C/D	E
Having breastfed the firstborn child										
1	A,D,E	705.01	764	−822.99				0.40	0.09	0.50
2	**A,E**	**705.03**	**765**	**−824.97**	**0.02**	**1**	**0.89**	**0.49**	—	**0.51**
3	E	722.94	766	−809.06	17.93	2	<.001	—	—	1
Firstborn child: BF <3, 3–6, and >6 months										
1	A,C,E	1,455.21	776	−96.79				0.44	0.00	0.56
2	**A,E**	**1,455.21**	**777**	**−98.79**	**0.00**	**1**	**1**	**0.44**	—	**0.56**
3	C,E	1,458.06	777	−95.94	2.85	1	0.09	—	0.35	0.65
4	E	1,483.11	778	−72.89	27.9	2	<.001	—	—	1
Average of all children: BF <3, 3–6 and >6 months										
1	A,C,E	1,496.66	776	−55.34				0.42	0.11	0.47
2	**A,E**	**1,496.93**	**777**	**−57.07**	**0.26**	**1**	**0.61**	**0.54**	—	**0.46**
3	C,E	1,499.89	777	−54.11	3.22	1	0.07	—	0.44	0.56
4	E	1,544.1	778	−11.9	47.44	2	<.001	—	—	1

Note: A = additive genetic factors, AIC = Akaike's information criterion, BF = breastfeeding, C = common environmental factors, D = dominant genetic factors, *df* = degrees of freedom, E = unique environmental factors, −2LL = twice the negative log-likelihood. Bold values indicate best-fitting models.

cases, with a non-significant χ^2 difference when compared with the full model. Additionally, this submodel showed the lowest values for the AIC.

The proportion of variance explained by A and E is similar when studying the three variables. In the first panel of Table 2, data about the initiation of BF in the firstborn child are shown. Following the information of the AE submodel, we can conclude that 49% of the variance presented in the behavior of having started to breastfeed the first child is explained by additive genetic sources. The rest of the variance (51%) is due to unique environmental effects. In the second and third panels, durations of BF for the firstborn child and for the average to all children are modeled. Data show that the variability in the duration of BF for the firstborn child is due to additive genetic and unique environmental effects, in a proportion of 44% and 56%, respectively. In the case of the average duration of BF, we found that individual differences are similarly explained by additive genetic (54%) and by unique environmental (46%) factors.

Discussion

Research in recent years has highlighted the multiple and substantial benefits of BF for the newborn, but also for the mothers who breastfeed, and the community where they live (World Health Organization Regional Office for Europe, 2000). The study of the factors influencing the decisions related to the baby's nutrition is an important goal for the understanding and promotion of BF, which can be conceptualized nowadays not only as a part of the reproductive cycle but also as a health behavior.

When a woman chooses to initiate BF, and when she decides to stop, multiple factors are playing a role. In this research, we aimed to contribute to the understanding of BF by exploring the different sources of the phenotypic variance observed in this behavior. For that sake, we analyzed the data provided by twin adult women who had been mothers at least once in their life. Our results show heritability estimates between 0.44 and 0.54 for the different variables studied, the rest of the variance being due to unique environmental factors. Not surprisingly, given the age of the sample, no evidence for the effect of shared environmental factors was found. These results suggest that the genetic factors have significant impact on the complex behavior of BF.

Genetic factors influencing the initiation and maintenance of BF could be linked to genes related to the production and activity of certain hormones that intervene in the underlying physiological processes of BF, such as prolactin and oxytocin. Prolactin stimulates milk production and secretion (Heinig & Dewey, 1997). As 'the great facilitator of life' (Lee et al., 2009), oxytocin is involved in several

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processes during and after childbirth, maternal behaviors, and bonding. Oxytocin could also be playing a role in the calmness reported by women while BF (Riordan, 2010).

Early cessation of BF has been frequently associated with factors that appear to have a biological origin, and could be indirectly influenced by our genetic makeup. Several studies have found that some of the most common reasons for BF cessation during the early postnatal period had to do with the physical discomforts of BF (Ahluwalia et al., 2005), breast pain, and soreness, latch-on and sucking disorganization or problems (Almqvist-Tangen et al., 2012; Taveras et al., 2003). Another frequent reason to stop BF is the women's uncertainty about the adequacy of their milk production (Ahluwalia et al., 2005; Taveras et al., 2003). Additionally, other factors that are associated with BF may also be genetically influenced. That is, the case of certain personality characteristics, like extraversion, openness, and agreeableness (Wagner et al., 2006), which are known to show substantial heritabilities (Plomin et al., 2008).

The presence of genetic effects contributing to the variance that we observe in BF behavior also appears logical from the point of view of evolutionary psychology. From this perspective, behavioral adaptations can be thought of as evolutionary answers to problems to which humans had to adapt (Plomin et al., 2008). Each mammal has developed over the course of millenniums a unique kind of milk for their necessities; and for humans BF has been a survival strategy (Landa Rivera, 2004). In fact, BF has been estimated to last between 2 and 4 years, throughout human existence (Paricio, 2004).

On the other side, unique environmental factors influencing the decisions and final behavior of BF could be those that have been receiving most attention in epidemiological research. Among them, the availability and length of maternity leave, health messages or experiences, contact with the peer group, social influence of significant others, and social norms and attitudes toward BF (Kools et al., 2005) could be highlighted. In addition, emotional, informational, and tangible support perceived by women (Ekstrom et al., 2003), and visual experience of BF (Barona-Vilar et al., 2009) have favored this behavior across time.

This research has some limitations that need to be taken into consideration. First, data collection through self-report is a tool with some well-known restrictions. In the case of BF data, the accuracy decreases as the period of recall increases further than 3 years (Li et al., 2005). While recognizing this problem, we think that our data provide a good approach for a valid estimation of the heritability in this behavior. In supporting this idea, our data show a good reliability. Some of the women in this sample ($n = 389$) provided data in 2007 and then again in 2009, and correlation between responses obtained at these two moments was highly significant ($r = 0.909$). Another limitation is that BF data analyzed in this study correspond to a period of more than 30 years, in which important changes in the social environment took place. These changes include some factors with a relevant and well-known impact on BF rates (Colodro-Conde et al., 2011). However, we have assumed that each twin pair has had their children in a limited range of time, not large enough to allow for social changes to differently affect each member of the pair. Altogether, in spite of the limitations mentioned, our findings can help us to understand the role and the impact of genetic and environmental factors on BF behavior.

In summary, this study provides a first estimate of the relative contribution of genetic and environmental factors to BF. The results suggest that approximately half of the inter-individual differences in BF initiation and maintenance are influenced by our genetic structure, while the rest is explained by unique personal experiences. Future interdisciplinary research may go deeper into this question and clarify the role of genetic factors in this relevant behavior, which in turn would help to improve the interventions focused on the health promotion of women and infants.

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