Twin Study of Heritability of Eating Bread in Danish and Finnish Men and Women

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Bread is an elementary part of the western diet, and especially rye bread is regarded as an important source of fibre. We investigated the heritability of eating bread in terms of choice of white and rye bread and use-frequency of bread in female and male twins in Denmark and Finland. The study cohorts included 575 Danish (age range 18–67 years) and 2009 Finnish (age range 22–27 years) adult twin pairs. Self-reported frequency of eating bread was obtained by food frequency questionnaires. Univariate models based on linear structural equations for twin data were used to estimate the relative magnitude of the additive genetic, shared environmental and individual environmental effects on bread eating frequency and choice of bread. The analysis of bread intake frequency demonstrated moderate heritability ranging from 37–40% in the Finnish cohort and 23–26% in the Danish cohort. The genetic influence on intake of white bread was moderate (24–31%), while the genetic influence on intake of rye bread was higher in men (41–45%) than in women (24–33%). Environmental influences shared by the twins were not significant. Consumption of bread as well as choice of bread is influenced by genetic predisposition. Environmental factors shared by the co-twins (e.g., childhood environment) seem to have no significant effects on bread consumption and preference in adulthood.

Keywords: twins, bread, rye, genes

Bread is one of the most important food items in the western diet and an important source of fiber. Bread also has a range of other positive health benefits such as contributing to satiety, containing a range of vitamins and minerals, as well as containing a high content of carbohydrates and a low content of fat. Bread is generally consumed in all western countries, but the types of bread that are consumed differ between cultures. Intake of rye bread is common in both Denmark and Finland. In both countries rye bread is considered to be a healthy choice of bread because of its high fiber content. In addition to fibre content, rye and wheat bread have other structural differences. Rye bread is formed by closely packed starch granules, whereas in wheat bread the starch granules are entrapped in an extensible gluten network (Juntunen et al., 2003). This causes a less porous and mechanically firmer structure in rye compared to wheat breads, which has been suggested to contribute to slower rate of hydrolysis and lower postprandial insulin response after the ingestion of rye than wheat bread (Juntunen et al., 2003; Leinonen et al., 1999). Similar effects were observed much earlier also in diabetic patients in Finland (Heinonen et al., 1985). Tests done in Finland have estimated the glycemic index (GI) of rye bread to be 77, and the GI of white wheat bread to be 89, with glucose solution used as reference (Hatonen et al., 2006). A rye breakfast appears to have day-long beneficial effects based on the postprandial response after lunch and dinner (Nilsson et al., 2008). Choosing rye bread, either from learned (environmental) or inherited predispositional influences, may thus improve glucose metabolism in several ways. Use of rye bread can thus potentially help in reducing risk of type 2 diabetes and in weight maintenance (Nilsson et al., 2008).

Received: 2 July, 2009; accepted 18 February, 2010.

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Previous studies have demonstrated that habitual dietary intake is influenced by both genetic and environmental factors (Hasselbalch et al., 2008). In the present study, we investigated the genetic and environmental influences on bread use-frequency and bread choice in twin samples from Denmark and Finland.

Materials and Methods

The GEMINAKAR Study

This study was part of the larger nation-wide, population-based Danish Twin Registry and its studies of the metabolic syndrome and related components. The GEMINAKAR sample consists of 756 complete twin pairs, who at the time of examination had no known diabetes or cardiovascular disease and were not pregnant, breast-feeding, abusing alcohol/drugs or having other conditions making it difficult to participate in the clinical examination. The zygosity was determined by polymorphic DNA markers. The method of ascertainment and characteristics of the cohort have been described in detail elsewhere (Benyamin et al., 2007; Schousboe et al., 2004). Dietary information was obtained through an extensive food frequency questionnaire, which has been described elsewhere (Hasselbalch et al., 2008). In brief, consumption of bread was assessed by asking the participants how often they ate half a slice of rye bread, a slice of wheat whole grain bread or a slice of white (wheat) bread with the following options: never, once a month, 2–3 times per month, 1–2 times per week, 3–4 times per week, 5–6 times per week, once a day, 2–3 times per day, 4–5 times per day, 6–7 times per day and 8 or more times per day. Dietary information was available for 575 complete twin pairs with an age range from 18–67 years, including 111 monozygotic male pairs (MZM), 107 dizygotic male pairs (DZM), 122 monozygotic female pairs (MZF), 113 dizygotic female pairs (DZF) and 122 dizygotic opposite sex pairs (DZOS). The GEMINAKAR study was approved by all the Danish regional scientific-ethical committees.

The FinnTwin16 Study

The Finnish data were derived from five consecutive and complete year cohorts of Finnish twins born 1975–1979 (Kaprio et al., 2002). The response rate of the baseline survey at age 16 was 88%. The data used in this study were based on the fourth wave of the study, conducted in 2000–2002. At the time of study, the subjects were 22–27 years of age, and the response rate was 88%. The questionnaire was sent only to the twin individuals who participated in the baseline survey, and thus this wave of the study comprises 77% of all twin individuals belonging to the five birth cohorts. Zygosity was determined by a deterministic algorithm using questions on physical similarity during school age, which has shown high validity in another Finnish twin cohort (Sarna et al., 1978). The bread intake was asked as the number of slices of bread consumed daily on average during the past year using an open question. These were asked separately for rye bread, whole grain bread or white (wheat) bread. Examples of each type were included in parentheses. We included 2009 (250 MZM, 308 DZM, 413 MZF, 360 DZF and 678 DZOS) Finnish adult twin pairs with information on bread intake. The study was approved by the Ethical Committee of Helsinki University Hospital and the Institutional Review Board of Indiana University.

Data Analysis and Statistical Methods

We created a measure of total bread consumption by summing the total number of slices of bread consumed daily. In addition the consumption of rye bread and other bread (whole wheat and white) were analyzed separately. The proportion of rye bread consumption relative to the total number of slices of bread was used as a measure of rye bread preference, the theoretical range of this variable thus being 0–1. Due to the skewed distribution of bread consumption, logarithmic values were used in the genetic analyses.

Analyses of twin data assume that intra-pair variance of MZ twins is due to environmental factors and measurement errors, while intra-pair variance in DZ twins in addition is affected by differences in genetic factors. It is also assumed that MZ and DZ twins share common environmental factors to a similar extent. Comparison of the intra-class correlation of the trait values in MZ twin pairs with that of DZ twin pairs can therefore provide a means of determining the genetic contribution to observed variation in the traits.

We compared different variance component models for each trait to see which provided the best overall fit in the genetic analyses. In this study, the tendency for DZ correlations to be about half or more than half of the MZ correlations lead to the consistent use of a model partitioning the total phenotypic variance (VP) into additive genetic (VA), shared environmental (VC), and individual environmental variance components (VE), the latter including variance due to measurement error. We have modeled and estimated variances under the assumption of no non-additive genetic effects, given the pattern of pairwise correlations in MZ and DZ twins. In addition we tested whether sex-specific effects were present in the data. The age of the twins was controlled for in the models by computing regression residuals with age as a response variable in the regression models. Mx, a structural equation modeling package for genetic analyses of twins and families, was used to compute the goodness of fit of the models and maximum likelihood parameter estimates (Neale et al., 2004).

Results

The average consumption of bread was five slices of bread per day in Denmark and four slices in Finland with slightly higher consumption among men than women for both countries (Table 1).

In general the intra-class correlations for MZ twins were higher than the intra-class correlations for DZ

Table 1

Bread Consumption in Denmark and Finland Among Men and Women (Median and 25% / 75% Llimits)

	Denmark		Finland	
	Men	Women	Men	Women
Total bread intake				
n slices per day	5.5 (3.5–8.0)	4.03 (2.84–5.5)	5 (3–7)	4 (3–5)
White bread use				
n slices per day	1.56 (0.5–2.5)	1 (0.5–2.5)	2 (1–4)	1 (-3)
Rye bread use				
n slices per day	3.5 (2–5.5)	2.5 (1.03–3.5)	2 (1–4)	2 (1–3)
Preference for rye bread				
rye bread / total bread	0.67 (0.65–0.69)	0.64 (0.62–0.66)	0.48 (0.46–0.49)	0.51 (0.50–0.52)

twins (Table 2). This indicates that bread consumption and bread choice are influenced by genetic factors that make MZ twins more alike. The DZ intra-class correlations tended to be about half or more than half of the MZ intra-class correlations. The higher DZ than MZ correlation of rye bread consumption in Danish women is possibly due to chance, since the 95% confidence intervals overlap. The lower intrapair correlations of opposite-sex DZ twins compared to same-sex DZ twins imply that sex-specific genetic and environmental influences may underlie the traits. The univariate model estimating the amount of the total phenotypic variance due additive genetic (A), shared environmental (C), and individual environmental (E) effects was therefore used as a starting point against which more parsimonious models were compared.

Fixing the estimates to be equal for men and women resulted in the majority of the models in a significantly worse fit of the model (p for model fit comparison based on χ^2-test = 2.40*10–9 – 0.09). The univariate analyses demonstrated sex-specific genetic and environmental influences on bread intake frequency as well as bread choice. The results of the univariate analyses are therefore shown separately for men and women. When comparing the ACE-model with the most parsimonious AE-model leaving out effects due to the shared environment, it did not lead to a significant worse fit of the model (*p* for model fit comparison based on χ^2-test = 0.10 – 0.87). None of the more parsimonious models were significantly different from the saturated models (p for model fit comparison based on χ^2-test = 0.08 – 0.39) suggesting that the assumptions of the twin model were valid in the data. The shared environment did not significantly contribute to bread consumption or bread choice.

The analysis of bread consumption demonstrated moderate heritability ranging from 37–40% in the Finnish cohort and 23–26% in the Danish cohort (Table 3). The genetic influences on intake of white bread were moderate (24–31%) in both countries and genders, whereas the genetic influences on intake of rye bread differed between the genders in both countries, with heritability estimates of 41–45% for men and 24–33% for women.

Discussion

The results of present study demonstrate that bread intake as well as choice of type of bread are partially

Table 2

Intraclass Correlations and Their 95% Confidence Intervals Across Sex and Zygosity Adjusted for Age

		MZM	DZM	MZF	DZF	DZOS
Total bread intake						
n slices per day	DK	0.25 (0.07–0.41)	0.18 (–0.01–0.36)	0.16 (–0.02–0.33)	0.26 (0.08–0.42)	0.03 (–0.16–0.21)
	FI	0.39 (0.28–0.49)	0.23 (0.12–0.33)	0.43 (0.35–0.51)	0.12 (0.01–0.22)	0.10 (0.02–0.17)
White bread use						
n slices per day	DK	0.14 (–0.14–0.32)	0.27 (0.08–0.44)	0.27 (0.10–0.43)	0.05 (–0.01–0.23)	0.27 (0.09–0.43)
	FI	0.32 (0.20–0.43)	0.12 (0.01–0.23)	0.31 (0.22–0.39)	0.14 (0.03–0.23)	0.08 (0.00–0.15)
Rye bread use						
n slices per day	DK	0.42 (0.26–0.56)	0.22 (0.03–0.39)	0.15 (–0.03–0.32)	0.34 (0.16–0.49)	0.12 (–0.07–0.30)
	FI	0.39 (0.28–0.49)	0.27 (0.16–0.37)	0.35 (0.26–0.43)	0.13 (0.03–0.23)	0.13 (0.05–0.20)
Preference for rye bread						
rye bread / total bread	DK	0.40 (0.23–0.54)	0.27 (0.08–0.44)	0.27 (0.09–0.43)	0.19 (0.00–0.37)	0.23 (0.05–0.40)
	FI	0.37 (0.26–0.47)	0.16 (0.05–0.27)	0.26 (0.16–0.34)	0.16 (0.06–0.26)	0.09 (0.01–0.16)

Note: DK: Denmark; FI: Finland; MZM: Monozygotic male twin pairs; DZM: Dizygotic male twin pairs; MZF: Monozygotic female twin pairs; DZM: Dizygotic male twin pairs; DZOS: Dizygotic opposite sex twin pairs.

Table 3

Standardized Variance Components from the Univariate Genetic Analyses of All Traits

		Men		Women	
		h^2	e^2	h^2	e^2
Total bread intake					
n slices per day	DK	0.26 (0.10–0.40)	0.74 (0.60–0.90)	0.23 (0.07–0.38)	0.77 (0.62–0.93)
	FI	0.37 (0.28–0.45)	0.63 (0.55–0.72)	0.40 (0.33–0.47)	0.60 (0.53–0.67)
White bread					
n slices per day	DK	0.24 (0.09–0.38)	0.77 (0.62–0.91)	0.28 (0.12–0.42)	0.72 (0.58–0.88)
	FI	0.31 (0.21–0.41)	0.69 (0.59–0.79)	0.30 (0.22–0.38)	0.70 (0.62–0.78)
Rye bread					
n slices per day	DK	0.45 (0.30–0.57)	0.56 (0.43–0.70)	0.24 (0.08–0.39)	0.76 (0.61–0.92)
	FI	0.41 (0.31–0.49)	0.60 (0.51–0.69)	0.33 (0.25–0.41)	0.67 (0.59–0.75)
Preference for rye bread					
rye bread / total bread	FI	0.48 (0.33–0.60)	0.52 (0.40–0.67)	0.29 (0.14–0.43)	0.71 (0.57–0.86)
	DK	0.37 (0.27–0.46)	0.63 (0.54–0.73)	0.27 (0.18–0.34)	0.74 (0.66–0.82)

Note: h^2 refers to the heritability, i.e. the proportion of variance attributable to genetic effects, while e^2 is the proportion of variance due to environmental effects.
DK: Denmark; FI: Finland; MZM: Monozygotic male twin pairs; DZM: Dizygotic male twin pairs; MZF: Monozygotic female twin pairs; DZM: Dizygotic male twin pairs; DZOS: Dizygotic opposite sex twin pairs.

under genetic control, whereas the environment shared by the twins seemed not to influence bread intake frequency or bread choice. This indicates that, for instance dietary habits acquired in the childhood home may not have a lasting effect on habits related to eating bread as adults. Thus, genetic and environmental influences on food choices are likely to evolve over time as the individual develops. While allowing for the inclusion of measurement errors, it appears that the individual environment has a considerable influence. In a public health perspective this indicates that there exists — despite the genetic influence — a potential for establishing healthy eating habits both at the individual and the family levels.

Rye is grown primarily in Eastern, Central and Northern Europe, and the consumption of rye in the main producing countries has been falling in the past years (http://www.fao.org/es/ess/top/commodity.html). Despite that, the proportion of bread slices eaten as rye was about 50%, or over, in both countries and among both sexes, indicating that rye bread continues to be a major component of diet.

This study was based on two relatively large population-based twin samples together covering the age range from 18–67 years. In attempt to remove possible confounding of disease status and/or medical treatment on the intraclass correlations, we excluded subjects having diagnosed diabetes or cardiovascular disease in the GEMINAKAR sample, while the Finnish sample consisted of mostly health young adults.

Gender differences in the heritability of intake of rye bread were found in both cohorts, indicating that the magnitude of the genetic influences on intake of rye bread were higher in men than in women. The greater heritability estimate for use of rye bread versus use of white bread, especially in men, may be due to genetically determined liability to perceive compounds, such as bitter compounds (Heinio et al., 2008), specific to rye bread. These compounds remain unknown, and should be further pursued using genetically informative study samples. Rye is typically prepared as dry rye crisp bread or as sourdough bread. We did not ask about the specific types of rye bread that were consumed. In Finland and Denmark, rye breads are generally not sweetened unlike in Sweden. Thus, the genetic effects on rye bread choice are not confounded by genetic effects on sweet choice (Keskitalo et al., 2007).

In conclusion, our study found genetic effects on overall bread use that were very similar in men and women from Finland and Denmark, whereas acquired bread preferences during childhood did not seem to play a role. Among men, genetic effects on rye bread consumption were further greater than for other bread variables. This could be due to inherited differences in taste preferences. Large individual differences have been demonstrated in human sensitivity toward specific dietary compounds (Tepper, 2008). This could not be examined in the present study, but more detailed studies on responses to rye bread in genetically informative samples might be a useful follow-up.

Acknowledgment

The present study was supported by the DIOGENES which is the acronym for 'Diet, Obesity and Genes' supported by the European Community (Contract no. FP6–513946), http://www.diogenes-eu.org/.

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