BMC Public Health

RESEARCH

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# The trend of correlation changes of macronutrient intakes among different familial pairs: a prospective study among participants of Tehran Lipid and Glucose Study

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## Abstract

**Background/Aim** Familial resemblance in dietary patterns has been a subject of interest, with both genetic and environmental factors playing crucial roles. This study aims to investigate trends in macronutrient intake correlations over a 9-year period among different familial pairs, including parent-offspring, siblings, and spouses, using data from the Tehran Lipid and Glucose Study (TLGS).

**Methods** This longitudinal study, conducted within the framework of the TLGS, analyzed data from 1,814 families over a 9-year period. Dietary intakes were assessed using a validated 168-item food frequency questionnaire. Macronutrient intakes were calculated and adjusted for age. Familial correlations were estimated using intraclass correlation coefficients for various familial pairs (parent-offspring, siblings, and spouses) across four consecutive surveys. Changes in correlations were analyzed over 3-year, 6-year, and 9-year intervals, as well as across all four surveys, to determine overall trends in macronutrient intake correlations.

**Results** The results revealed diverse trends in intake correlations for carbohydrates, proteins, fats, and specific fatty acids across familial relationships. Parent-offspring dyads exhibited varied patterns, with some nutrients showing regression to the mean. Sister-sister pairs demonstrated strengthening correlations for energy, carbohydrates, fats, and saturated fatty acids over time. Conversely, brother-sister pairs displayed weakening correlations for most macronutrients, particularly energy, proteins, cholesterol, and fiber. Spouse correlations tended towards regression to the mean for energy, carbohydrates, and fats, and fiber.

**Conclusions** The present study illuminates the dynamic nature of familial dietary correlations over time. The contrasting trends between sister-sister and brother-sister dyads suggest a significant influence of gender on shared

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dietary patterns. These findings underscore the complex interplay of genetic and environmental factors in shaping family dietary behaviors and highlight the importance of considering both gender and relationship type when examining familial nutritional habits.

**Keywords** Diet, Macronutrients, Correlation coefficients, Family, Genetics, Environment

## Introduction

Research has demonstrated that nutritional traits, including food intake, show similarities among family members, primarily due to genetic factors and shared family environment, with these influences being particularly significant during early life stages [1, 2]. Parents shape their children's eating behaviors through genetic and environmental influences [3]. The family unit provides an ideal setting for studying these genetic and environmental effects on dietary intake. Parental decisions about food choices, preparation methods, meal patterns, and dining locations significantly shape a child's food environment and attitudes [4].

While previous research generally shows weak to moderate correlations between parents' and offspring's dietary intakes [1, 5], findings vary across populations and nutrients. A meta-analysis revealed average familial correlations of 20% for fat and 21% for energy intake, with variations among specific parent-child pairs [1]. Interestingly, an Iranian study found significant correlations across parent-child pairs for most nutrients, suggesting potential cultural or regional differences in familial dietary patterns [5]. Despite these findings, the long-term stability of familial dietary resemblance remains unclear. Young individuals' eating patterns are influenced by various complex factors, including the family environment, along with other social and biological factors affecting dietary intake. Studies have observed that as children grow older, the family's influence on food choices gradually diminishes [6]. While previous studies investigated familial correlations using cross-sectional designs, the longitudinal changes in familial resemblance of macronutrient intake remain understudied. It is unclear whether this resemblance remains constant, decreases over time, or follows no specific pattern. Moreover, research on sibling pairs' dietary similarities is limited, particularly regarding changes in macronutrient intake resemblance over time.

Therefore, this study aims to examine trends in macronutrient intake correlations across different Tehran Lipid and Glucose Study (TLGS) surveys among various familial pairs, including parent-offspring (father-son, mother-son, father-daughter, mother-daughter), siblings (brother-brother, brother-sister, sister-sister), and spouses. Our findings can contribute to understanding the roles of genetics and familial habits in food intake patterns, which is crucial for developing targeted nutritional interventions and policies that consider the changing dynamics of familial dietary influences over time.

## Materials and methods

### Study participants and genealogy data

The present study was conducted within the framework of TLGS, an ongoing community-based prospective study involving a sample of residents from District No. 13 of Tehran, the capital city of Iran. District 13 was chosen for the TLGS due to its high population stability and diverse demographic composition, including residents from various economic and social backgrounds. This district was considered representative of Tehran's overall population, enhancing the study's generalizability to the broader urban context of Tehran [7]. The first survey of the TLGS began in March 1999, with data collection occurring at 3-year intervals and continuing to the present. The baseline survey was a cross-sectional study conducted from 1999 to 2001, followed by prospective follow-up surveys: survey 2 (2002–2005), survey 3 (2006–2008), survey 4 (2009–2011), survey 5 (2012–2014), and survey 6 (2015–2018). Details of the TLGS design and its preliminary results have been described elsewhere [8]. Additionally, within the framework of the TLGS, the Tehran Cardio-Metabolic Genetic Study (TCGS) was established as a prospective family-based cohort study with a 3-year interval follow-up period. Its objective is to create a comprehensive genome-wide database and gather familial data from the population of Tehran city [9].

The TLGS participants were evaluated for familial relationships, genetic data, dietary intakes, anthropometric parameters, and biochemical factors. For this study, we included TLGS participants from surveys 3–6 ($n$=3568, 7956, 7052, and 7720, respectively) who met the following criteria: age ≥ 18 years, non-pregnant/non-lactating, not adhering to a special diet (for weight loss or management of pre-existing chronic disease), no having under-reporting or over-reporting of energy intake (≤ 800 kcal/day and ≥ 4200 kcal/day, respectively), no history of cancer or cardiovascular events, and with complete dietary data initially measured during the first survey.

For the assessment of 3-year changes in correlation of macronutrient intakes, participants from the third survey who had complete dietary and familial data in the subsequent survey (survey 4) were selected. Correlation analyses were conducted separately for surveys 3 and 4. Similarly, for the evaluation of 6-year changes in correlation of macronutrient intakes, participants from the third

survey with complete dietary and familial data in survey 5 were included. Correlation analyses were performed for surveys 3 and 5. To analyze 9-year changes in correlation of macronutrient intakes, participants from the third survey with complete dietary and familial data in survey 6 were selected. Correlation analyses were conducted for surveys 3 and 6.

Furthermore, to determine the overall trends in macronutrient intake correlations among different familial pairs participating in the TLGS study across surveys 3 to 6, a group of adults with complete dietary and familial data across all surveys (3, 4, 5, and 6) was selected. Four separate analyses of macronutrient correlations were conducted. We presented the findings using graphs, connecting the correlation values of each analysis with lines to illustrate the trends in correlation changes across different surveys for various familial pairs.

#### Dietary assessments

The dietary intakes of the study population were assessed using a validated and reliable semi-quantitative 168-item food frequency questionnaire (FFQ) [10, 11]. In each survey, trained dieticians conducted face-to-face interviews where subjects reported the frequency of consuming each food item in household measures over the previous year, indicating whether consumption was daily, weekly, or monthly. Food frequencies were recorded in an Excel spreadsheet and subsequently converted into grams for analysis.

#### Macronutrients

The energy content of consumed foods was primarily calculated using the United States Department of Agriculture (USDA) food composition table (FCT), available at https://fdc.nal.usda.gov/fdc-app.html. To address local food variations not covered by the USDA FCT, we utilized the Iranian Food Composition Table (FCT). This approach allowed us to accurately analyze and account for local food items specific to the Iranian diet that were not represented in the USDA database. The Iranian FCT provided nutritional information for traditional Iranian dishes, local ingredients, and regional food preparations that are unique to the Iranian cuisine. When encountering a food item not found in the USDA FCT, we first consulted the Iranian FCT to obtain the most culturally appropriate and accurate nutritional data. This ensured that our analysis captured the true nutritional profile of the local diet. In cases where a direct match for a local food item was not found in either database, we used the closest equivalent or a combination of similar ingredients to estimate its nutritional content. This method allowed us to maintain consistency in our analysis while accounting for the diversity of the local diet.

To account for variability in total energy intake among participants, all nutrient intakes were standardized to 1000 kcal consumed. This energy adjustment allows for more accurate comparisons between individuals with different total energy intakes.

Daily intake calculations included energy and macronutrients (expressed as grams per day and as a percentage of total kcal), such as carbohydrates, protein, fats, saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), and trans fatty acids (TFA). Furthermore, dietary intake per 1000 kcal was calculated for cholesterol, fiber, and caffeine.

#### Statistical analysis

Dietary macronutrient intakes for each participant were adjusted for age by calculating the residuals from a regression of nutrient intakes on age. These residuals, representing the variation in dietary intake not explained by age, were then used in subsequent analyses. Following age adjustment, we normalized the residuals to account for differences in total energy intake across participants. Including age as a covariate in the analysis was done to control for potential confounding effects that could arise from age-related differences in dietary behaviors. The normalization process involved scaling the values by subtracting the mean and dividing by the standard deviation (z-score normalization). Our family-based recruitment naturally controlled for some potential confounding factors such as socioeconomic status and living environment, as family members typically share similar conditions.

Pedigree information was reported using the S.A.G.E. software. Pedigree information was analyzed using S.A.G.E. software, the FCOR command to estimate intraclass correlation coefficients (ICCs) between different familial pairs, including siblings and parent-child relationships. Our pedigree data included familial identifiers (FID, IID), parental information, and sex, along with normalized, age-adjusted nutrient intake values for each individual. P-value $< 0.05$ was considered statistically significant for ICCs. To address the risk of Type I error due to multiple comparisons, a Bonferroni correction was applied where necessary. Additionally, Tukey's HSD test was conducted following ANOVA to identify significant differences between different phases of the study. Graphs were generated using Prism Graph Pad software to visually represent our findings.

The significance threshold of 5% for familial correlations was established based on the study's data characteristics and research objectives. This threshold was chosen to balance the need for detecting meaningful changes with the practicality of result presentation, allowing for a focused yet comprehensive analysis of nutritional shifts across phases.

**Table 1** Population characteristics during the three-, six-, and nine-year follow-up of adults participated in the third survey of Tehran lipid and glucose cohort study

| Nutrient intake | 3 years transition($n=1773$) | | | 6 years transition($n=1617$) | | | 9 years transition($n=1352$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | S3 | S4 | *P*-value | S3 | S5 | *P*-value | S3 | S6 | *P*-value* |
| Age (year) | 34.7 ± 14.8 | 37.8 ± 14.8 | < 0.001 | 35.0 ± 15.2 | 41.2 ± 15.2 | < 0.001 | 35.8 ± 15.4 | 45.7 ± 4.9 | < 0.001 |
| Male (%) | 45.1 | 45.1 | - | 46.6 | 46.6 | - | 47.4 | 47.4 | - |
| BMI (kg/m$^2$) | 25.8 ± 5.22 | 26.6 ± 5.14 | < 0.001 | 25.8 ± 5.31 | 27.2 ± 5.14 | < 0.001 | 25.9 ± 5.16 | 27.7 ± 4.88 | < 0.001 |
| **Dietary intakes** | | | | | | | | | |
| Energy intake (Kcal/d) | 2297 ± 763 | 2419 ± 785 | < 0.001 | 2290 ± 762 | 2278 ± 728 | 0.65 | 2304 ± 774 | 2222 ± 707 | 0.004 |
| Carbohydrate (% of Kcal) | 56.6 ± 7.19 | 58.9 ± 6.69 | < 0.001 | 57.4 ± 7.12 | 59.1 ± 6.39 | < 0.001 | 57.5 ± 7.23 | 59.8 ± 6.25 | < 0.001 |
| Protein (% of Kcal) | 13.6 ± 2.46 | 14.8 ± 3.08 | < 0.001 | 13.5 ± 2.29 | 14.7 ± 2.52 | < 0.001 | 13.5 ± 2.26 | 15.2 ± 3.93 | < 0.001 |
| Fat (% of Kcal) | 31.3 ± 7.05 | 29.6 ± 5.95 | < 0.001 | 31.5 ± 6.98 | 29.3 ± 5.97 | < 0.001 | 31.4 ± 7.04 | 28.8 ± 5.79 | < 0.001 |
| PUFA (% of Kcal) | 6.54 ± 2.36 | 5.97 ± 1.91 | < 0.001 | 6.57 ± 2.27 | 5.94 ± 1.88 | < 0.001 | 6.52 ± 2.24 | 5.83 ± 1.80 | < 0.001 |
| MUFA (% of Kcal) | 10.8 ± 2.85 | 9.86 ± 2.79 | < 0.001 | 10.9 ± 2.80 | 9.80 ± 2.48 | < 0.001 | 10.86 ± 2.80 | 9.75 ± 2.35 | < 0.001 |
| SFA (% of Kcal) | 10.6 ± 5.46 | 9.68 ± 2.76 | < 0.001 | 10.6 ± 3.22 | 9.47 ± 2.61 | < 0.001 | 10.59 ± 3.04 | 9.20 ± 2.67 | < 0.001 |
| Trans FA (% of Kcal) | 0 | 0 | < 0.001 | 0 | 0 | 0.12 | 0 | 0 | < 0.001 |
| Cholesterol (mg/1000Kcal) | 99.3 ± 47.3 | 94.4 ± 39.8 | 0.001 | 98. 9 ± 49.6 | 93.7 ± 37.9 | 0.001 | 98.9 ± 49.1 | 93.5 ± 38.7 | 0.002 |
| Fiber (g/1000Kcal) | 16.3 ± 6.60 | 19.46 ± 7.83 | < 0.001 | 16.2 ± 6.64 | 18.4 ± 6.05 | < 0.001 | 16.2 ± 6.75 | 19.4 ± 6.55 | < 0.001 |
| Caffeine (mg/1000Kcal) | 44.3 (25.5–72.6) | 40.5 (23.4–70.4) | 0.01 | 42.7 (25.0 -70.5) | 46.3 (24.3–74.3) | 0.75 | 44.6 (25.6–73.9) | 45.7 (26.5–72.0) | 0.100 |

Data are expressed as mean ± SD and percentage (%) for continuous and categorical variables, respectively

*P-values were computed using the independent sample t-test for continues variables

**Table 2** Population characteristics of a group of adults participated in the third survey of Tehran lipid and glucose cohort study during the third, fourth, fifth, and sixth surveys of the study

| Nutrient intake | Four survey transition ($n=748$) | | | | *P*-values** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | S3 | S4 | S5 | S6 | ANOVA | 3–4 | 3–5 | 3–6 | 4–5 | 4–6 | 5-6 |
| Age (year) | 35.2 ± 14.5 | 38.3 ± 14.5 | 41.4 ± 14.5 | 45.2 ± 14.0 | * | * | * | * | * | * | * |
| Male (%) | 47.7 | 47.7 | 47.7 | 47.7 | - | - | - | - | - | - | - |
| BMI (kg/m$^2$) | 25.6 ± 4.93 | 26.4 ± 4.77 | 26.9 ± 4.60 | 27.4 ± 4.48 | * | † | * | * | ‡ | * | † |
| **Dietary intakes** | | | | | | | | | | | |
| Energy intake (Kcal/d) | 2308 ± 749 | 2384 ± 758 | 2283 ± 717 | 2210 ± 704 | * | ‡ | NS | † | † | * | ‡ |
| Carbohydrate (% of Kcal) | 57.6 ± 7.13 | 59.2 ± 6.52 | 59.5 ± 6.27 | 60.1 ± 6.36 | * | * | * | * | NS | ‡ | NS |
| Protein (% of Kcal) | 13.6 ± 2.16 | 14.9 ± 2.64 | 14.7 ± 2.66 | 15.3 ± 4.23 | * | * | * | * | NS | † | † |
| Fat (% of Kcal) | 31.3 ± 7.04 | 29.1 ± 5.68 | 28.9 ± 5.80 | 28.6 ± 5.88 | * | * | * | * | NS | † | NS |
| PUFA (% of Kcal) | 6.50 ± 2.26 | 5.85 ± 1.72 | 5.95 ± 1.87 | 5.82 ± 1.79 | * | * | * | * | NS | NS | NS |
| MUFA (% of Kcal) | 10.8 ± 2.79 | 9.67 ± 2.65 | 9.69 ± 2.59 | 9.70 ± 2.43 | * | * | * | NS | NS | NS | NS |
| SFA (% of Kcal) | 10.6 ± 3.10 | 9.67 ± 2.88 | 9.31 ± 2.55 | 9.16 ± 2.68 | * | * | * | * | ‡ | † | NS |
| Trans FA (% of Kcal) | 0.0001 ± 0.000 | 0.24 ± 0.25 | 0.003 ± 0.05 | 0.01 ± 0.16 | † | † | NS | ‡ | † | NS | ‡ |
| Cholesterol(mg/1000Kcal) | 99.6 ± 51.1 | 93.1 ± 37.2 | 92.2 ± 37.9 | 95.4 ± 39.3 | † | † | † | NS | NS | NS | NS |
| Fiber(g/1000Kcal) | 16.5 ± 6.74 | 20.0 ± 8.87 | 18.7 ± 6.30 | 19.7 ± 7.02 | * | * | * | * | * | NS | † |
| Caffeine(mg/1000Kcal) | 57.1 ± 54.2 | 52.3 ± 41.1 | 53.8 ± 40.5 | 53.8 ± 39.5 | NS | ‡ | NS | NS | NS | NS | NS |

**P values of ANOVA indicates the general differences between all surveys. P-values for two-by-two differences between surveys were obtained using Post-hoc Tukey test

*$P<0.001$. †$P<0.01$. ‡$P<0.05$

## Results

Among the 3,324 eligible participants in the third survey of TLGS, pedigree analysis revealed 1,814 families comprising 4,206 parent-offspring pairs and 667 sibling pairs (198 sister-sister, 151 brother-brother, and 318 sister-brother pairs).

### Baseline information

Table 1 summarizes population characteristics during the three-, six-, and nine-year follow-up periods. Across all time periods, participants showed consistent increases in age, BMI, and intake of carbohydrates, protein, and fiber. Conversely, fat, MUFA, PUFA, SFA, and cholesterol intake decreased. Energy intake decreased only during the 9-year period, while caffeine intake decreased over the 3-year period.

Population characteristics across the four surveys (third to sixth) are presented in Table 2. Over the 9-year follow-up period, significant changes were observed in most variables, with the exception of caffeine intake. The

mean age increased consistently from the third to the sixth survey. BMI also rose significantly throughout the surveys. Energy intake showed significant changes across surveys, except between the 3rd and 5th. For macronutrient intake, protein intake exhibited significant shifts in most comparisons, while carbohydrate and fat intake demonstrated significant changes only between the 4th and 5th surveys. SFA and fiber intake showed significant alterations, except between the 5th and 6th surveys. PUFA intake showed statistical significance in all comparisons involving the 3rd survey (3–4, 3–5, and 3–6). MUFA and cholesterol intake showed significant changes only between surveys 3–4 and 3–5. TFA intake showed significant changes across all phases except between surveys 3–5 and 4–6. Caffeine intake showed a significant shift only between the 3rd and 4th surveys.

#### Familial correlations

To enhance clarity and manage the complexity of analyzing numerous nutrients across multiple phases, a significance threshold of 5% was applied to determine meaningful changes between phases. Only differences exceeding this threshold were considered statistically significant and are reported in the findings.

#### Parent-offspring

Figure 1 depicts macronutrient correlation changes in parent-son pairs over 3, 6, and 9 years. In father-son pairs, energy and caffeine intake generally increased across all periods, while most other macronutrients showed decreasing trends. Protein intake remained notably stable across the 3-year, 6-year, and 9-year follow-ups. Among mother-son pairs, in the initial three years, protein and PUFA intake increased, while energy, carbohydrate, SFA, TFA, cholesterol, and fiber intake decreased. From surveys 3 to 5, energy and caffeine intake rose, contrasting with declines in carbohydrate, protein, SFA, and cholesterol intake. The 9-year period showed increases in fat, MUFA, and caffeine intake, accompanied by decreases in energy, protein, SFA, TFA, cholesterol, and fiber intake.

Figure 2 shows the correlation changes of macronutrients in father-daughter and mother-daughter pairs during 3-year, 6-year, and 9-year follow-ups. In father-daughter dyads, the correlation of carbohydrate, protein, fat, PUFA, MUFA, and TFA intake increased, while it decreased for energy and caffeine. During surveys 3 to 5, protein and cholesterol correlation increased, while energy, fat, PUFA, MUFA, SFA, fiber, and caffeine decreased. Over 9 years of follow-up between surveys 3 to 6, cholesterol intake increased, while energy, protein, fat, PUFA, MUFA, SFA, TFA, and fiber decreased. Over 3 years, the correlation of all dietary intakes decreased among mother-daughter pairs, except for fiber and caffeine. After 6 years, carbohydrate, fat, MUFA, and TFA intake increased, while energy, protein, and caffeine decreased. After 9 years, carbohydrate, fat, and MUFA intake increased, while energy, protein, TFA, cholesterol, fiber, and caffeine decreased.

Figure 3 shows macronutrient correlation changes over 9 years with four measurements in parent-offspring dyads. Most macronutrients exhibited a regression to the mean pattern across all dyads. In father-daughter pairs, energy, fat, MUFA, SFA, cholesterol, and fiber showed decreasing trends. Mother-daughter pairs saw increasing trends for carbohydrate, fat, and MUFA, with a decrease in fiber. Father-son pairs demonstrated an increasing trend for caffeine and decreasing trends for carbohydrate, fat, PUFA, and cholesterol. Mother-son pairs showed increasing trends for fat and MUFA, with a decrease in cholesterol.

#### Spouses and siblings

Figure 4 illustrates the variations in macronutrient correlations among brother-brother and sister-sister pairs over 3-year, 6-year, and 9-year follow-up periods. In brother-brother pairs, over the initial 3-year period, correlations for carbohydrate and fiber intake increased, while energy, protein, SFA, TFA, and caffeine correlations decreased. By the 6-year mark, energy and cholesterol correlations increased, while correlations for protein, fat, PUFA, MUFA, and caffeine decreased. After 9 years, correlations for energy, carbohydrate, fat, cholesterol, and fiber intake increased, while PUFA, SFA, TFA, and caffeine correlations decreased. Among sister-sister pairs, during the first 3 years, correlations for carbohydrate, fat, MUFA, SFA, and caffeine intake increased, while energy, protein, PUFA, TFA, cholesterol, and fiber correlations decreased. From surveys 3 to 5, energy intake correlations increased, while all other macronutrient correlations decreased except for caffeine. Over the 9-year period, energy, carbohydrate, fat, and SFA intake correlations increased, while protein, PUFA, cholesterol, fiber, and caffeine correlations tended to decrease.

Figure 5 depicts changes in macronutrient correlations among brother-sister dyads and spouses over three distinct follow-up periods: 3 years, 6 years, and 9 years. Brother-sister dyads showed varying trends across different time periods. In the initial 3-year period, correlations decreased for most macronutrients (energy, carbohydrates, protein, fat, PUFA, MUFA, cholesterol, and fiber), with the exception of increased TFA. From the 3rd to the 5th survey, correlations for energy, carbohydrates, protein, and caffeine decreased, while MUFA, PUFA, and cholesterol increased. Over the 9-year period, MUFA, PUFA, SFA, cholesterol, and caffeine correlations increased, whereas energy, carbohydrates, protein, TFA, and fiber correlations decreased. Spouse correlations exhibited distinct patterns. During the 3-year follow-up,

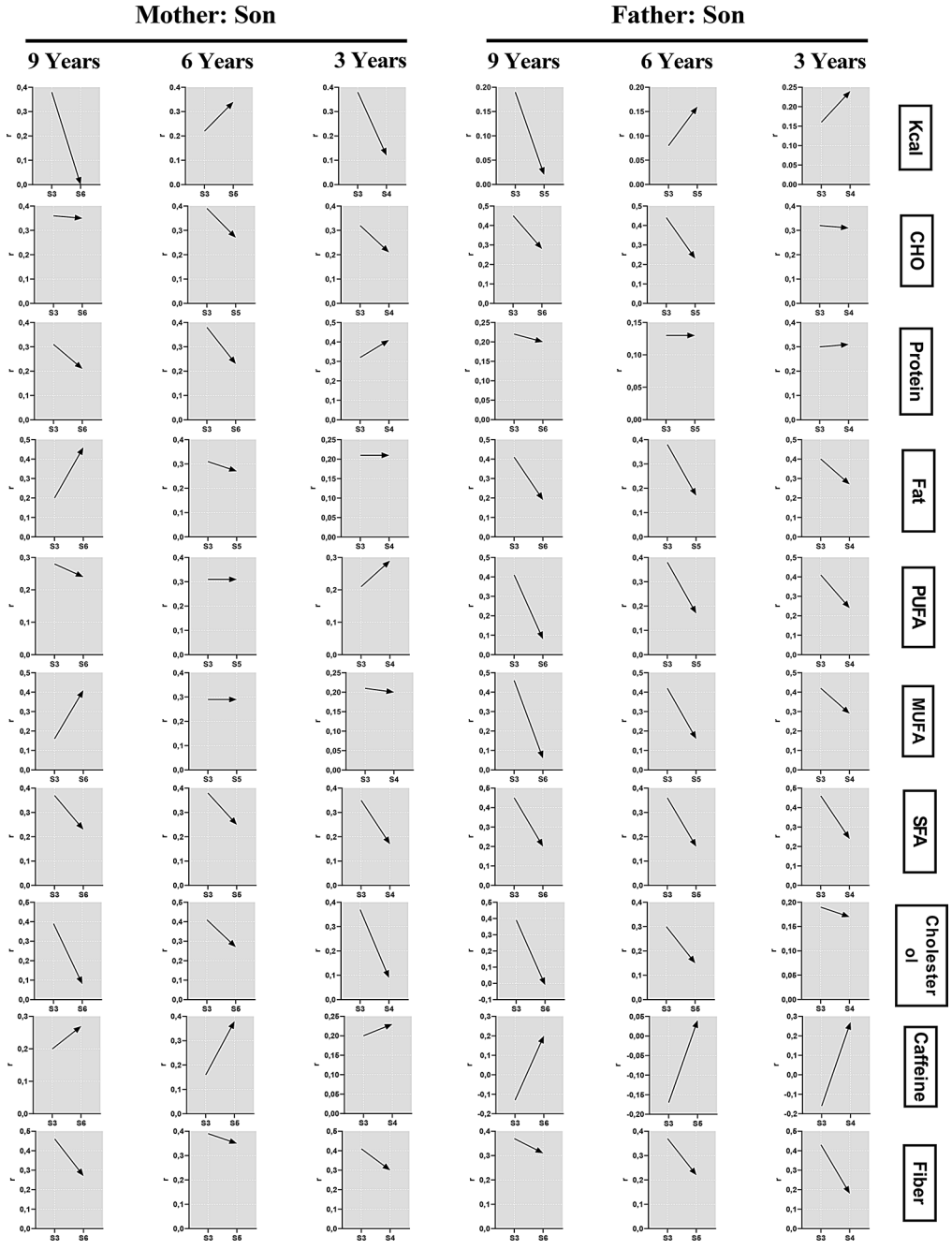


**Fig. 1** Macronutrient correlation changes in parent-son pairs over 3, 6, and 9 years

correlations for MUFA, caffeine, and fiber decreased. The 6-year follow-up saw increases in energy, carbohydrates, protein, and TFA correlations, with notable decreases in cholesterol and fiber. Over the 9-year period, correlations decreased for most macronutrients (carbohydrates, fat, PUFA, MUFA, SFA, cholesterol, and fiber), with the exception of caffeine, which increased.

Figure 6 shows the correlation changes of macronutrients over a 9-year follow-up with four consecutive measurements in siblings and spouses. Brother-brother pairs showed regression to the mean for energy, protein, and caffeine, with increasing correlations for SFA and fiber over the four phases. Sister-sister pairs exhibited regression patterns for several nutrients (energy, fat, TFA, cholesterol, and fiber), an increase in PUFA, and a decrease in caffeine correlations over the same period. Brother-sister pairs demonstrated regression to the mean for multiple nutrients (carbohydrate, fat, MUFA, PUFA, SFA, and caffeine), with decreasing correlations for energy, protein, TFA, cholesterol, and fiber. For spouses continuously

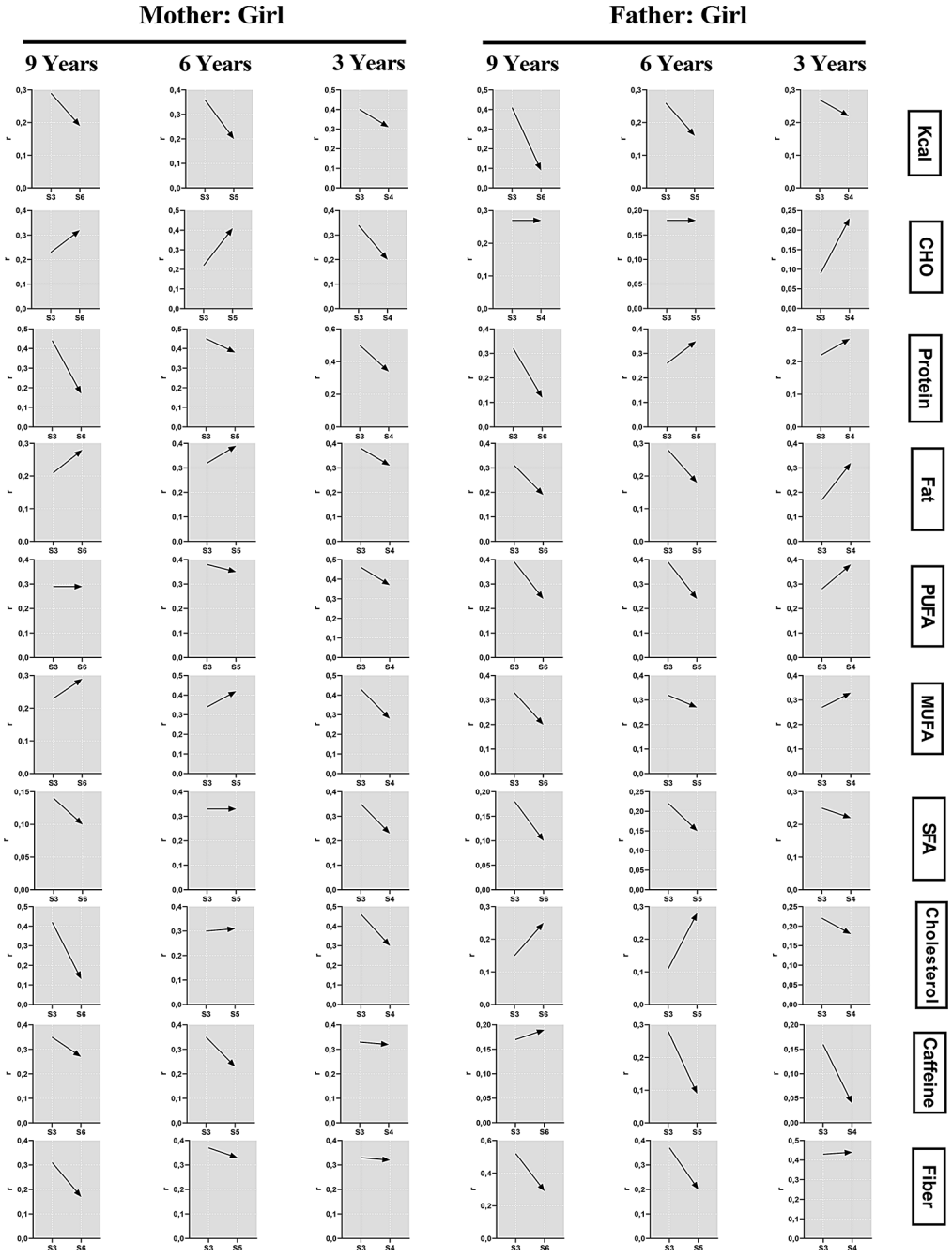


**Fig. 2** Macronutrient correlation changes in parent-daughter pairs over 3, 6, and 9 years

present over the four phases, regression to the mean was observed for several nutrients (energy, carbohydrate, fat, PUFA, MUFA, and fiber), correlations remained unchanged for protein and caffeine, and decreased for cholesterol intake correlation.

## Discussion

The present study examined changes in macronutrient intake correlations among various familial pairs, parent-offspring, siblings, and spouses, over three distinct follow-up periods of 3, 6, and 9 years, as well as across four consecutive measurements within the 9-year span. Our findings revealed significant variations in the correlations of different macronutrient intakes, indicating dynamic patterns of dietary behaviors within families over time.

Previous research on familial dietary similarities has predominantly focused on overall dietary patterns and food group consumption, and nutrient with limited attention given to macronutrient intake correlations

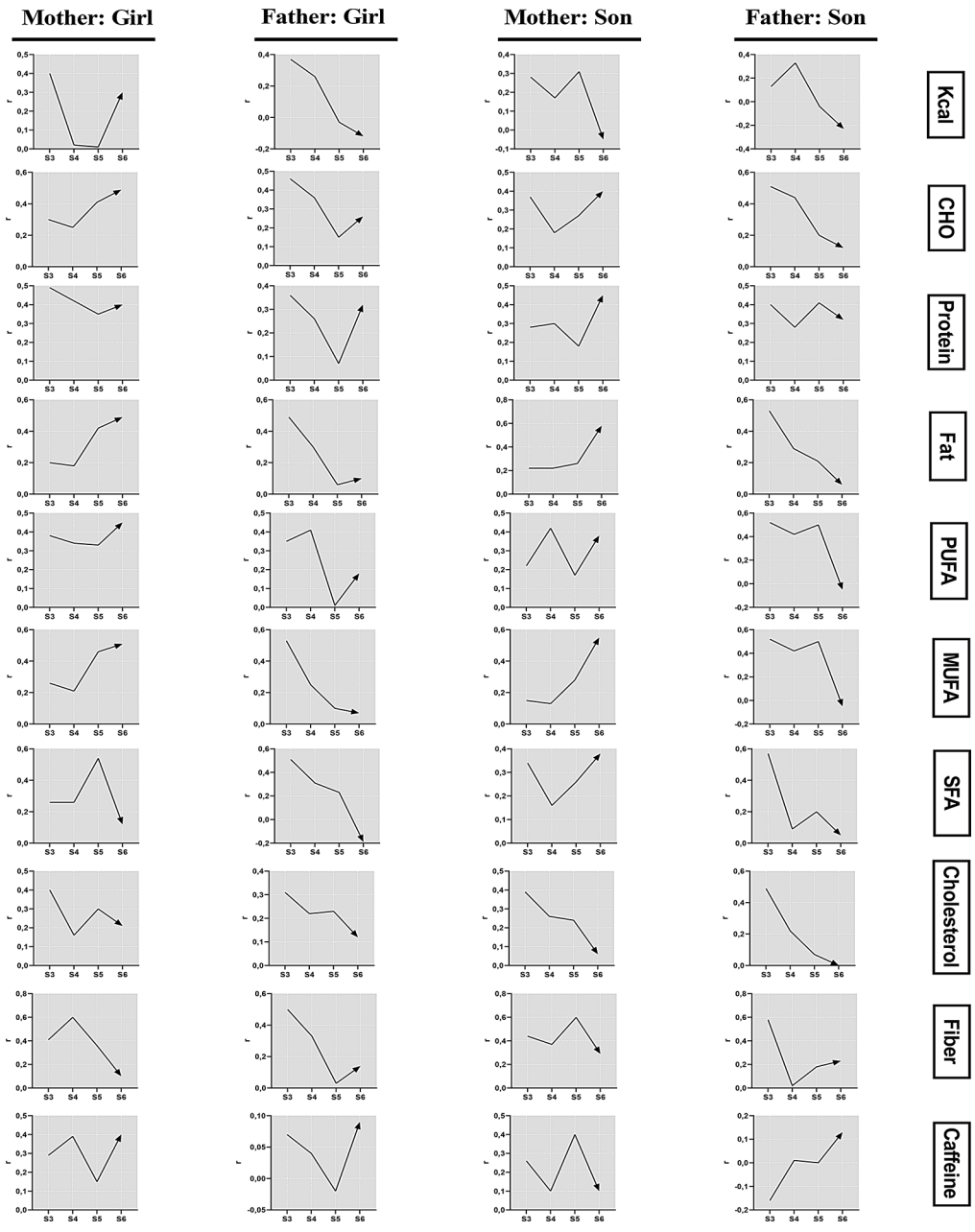


**Fig. 3** Changes in macronutrient correlation over 9 years with four measurements in parent-offspring dyads

[1]. A recent meta-analysis found that the resemblance between parent-child pairs in terms of dietary intake variables, including energy, nutrients, food groups, and overall diet, was weak to moderate [12], although some studies reported no significant associations [13, 14]. However, these studies primarily addressed parent-child correlations, leaving it unclear how these relationships change over time, particularly when siblings and spouses are also considered in the analysis.

In the present study, one of the most notable observations was the regression towards the mean pattern exhibited by certain macronutrient intakes in specific familial pairs, particularly evident when examining correlations across four consecutive measurements during the 9-year follow-up period. This phenomenon was observed in father-daughter pairs for carbohydrate, protein, PUFA, TFA, and caffeine intake correlations, and in mother-daughter pairs for energy, protein, PUFA, TFA, caffeine, and cholesterol intake correlations. Similar patterns were also noted in father-son and mother-son pairs for various macronutrients. This regression towards the mean suggests that initial deviations in dietary intake correlations within these familial dyads tend to be corrected or adjusted over time, eventually converging towards the

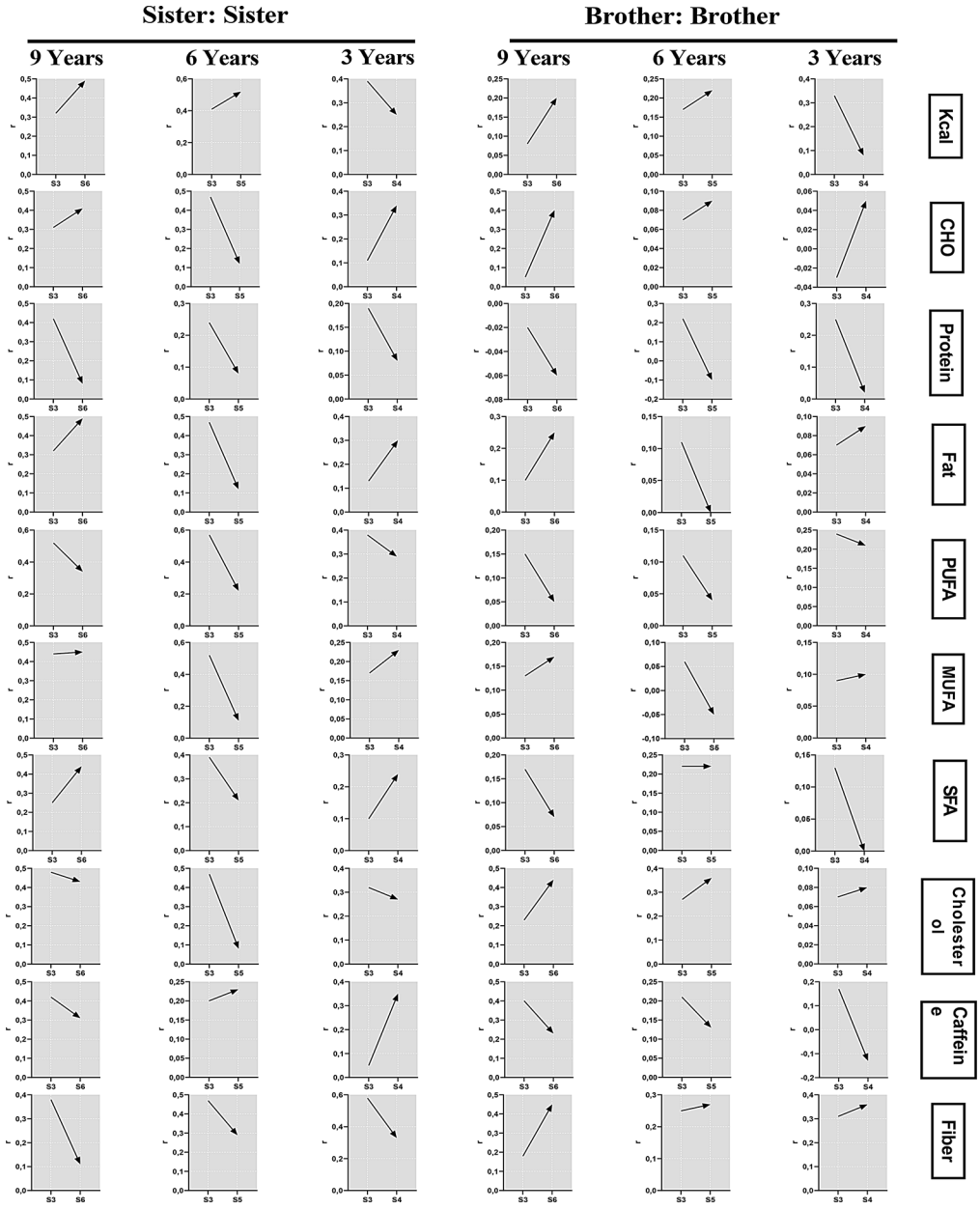


**Fig. 4** Changes in macronutrient correlations among brother-brother and sister-sister pairs over 3-year, 6-year, and 9-year follow-up periods

population average. The presence of this phenomenon has important implications for understanding long-term dietary behaviors within families. It underscores the complex interplay between individual dietary choices and familial influences, suggesting that while short-term fluctuations in dietary similarities exist, there are underlying factors that stabilize family members' diets over time. These factors may include shared genetic predispositions, common environmental influences, or adaptive behaviors within the family unit [15]. Interestingly, divergent trends were observed across different familial relationships, underscoring the potential influence of gender-specific dynamics and sociocultural factors on dietary behaviors within families. For example, while father-offspring pairs displayed a decrease in most macronutrient intake correlations over the 9-year follow-up period, mother-offspring pairs exhibited an increase in carbohydrate, fat and MUFA intake correlations during the same timeframe. These contrasting patterns are consistent with existing literature, which indicates that parental influence on children's dietary habits may be gender-dependent. Prior studies have demonstrated a stronger positive correlation between mothers' and children's diets compared to fathers' and children's diets [5, 16, 17]. This suggests that maternal dietary habits may have a more significant impact on offspring nutrition [18, 19].

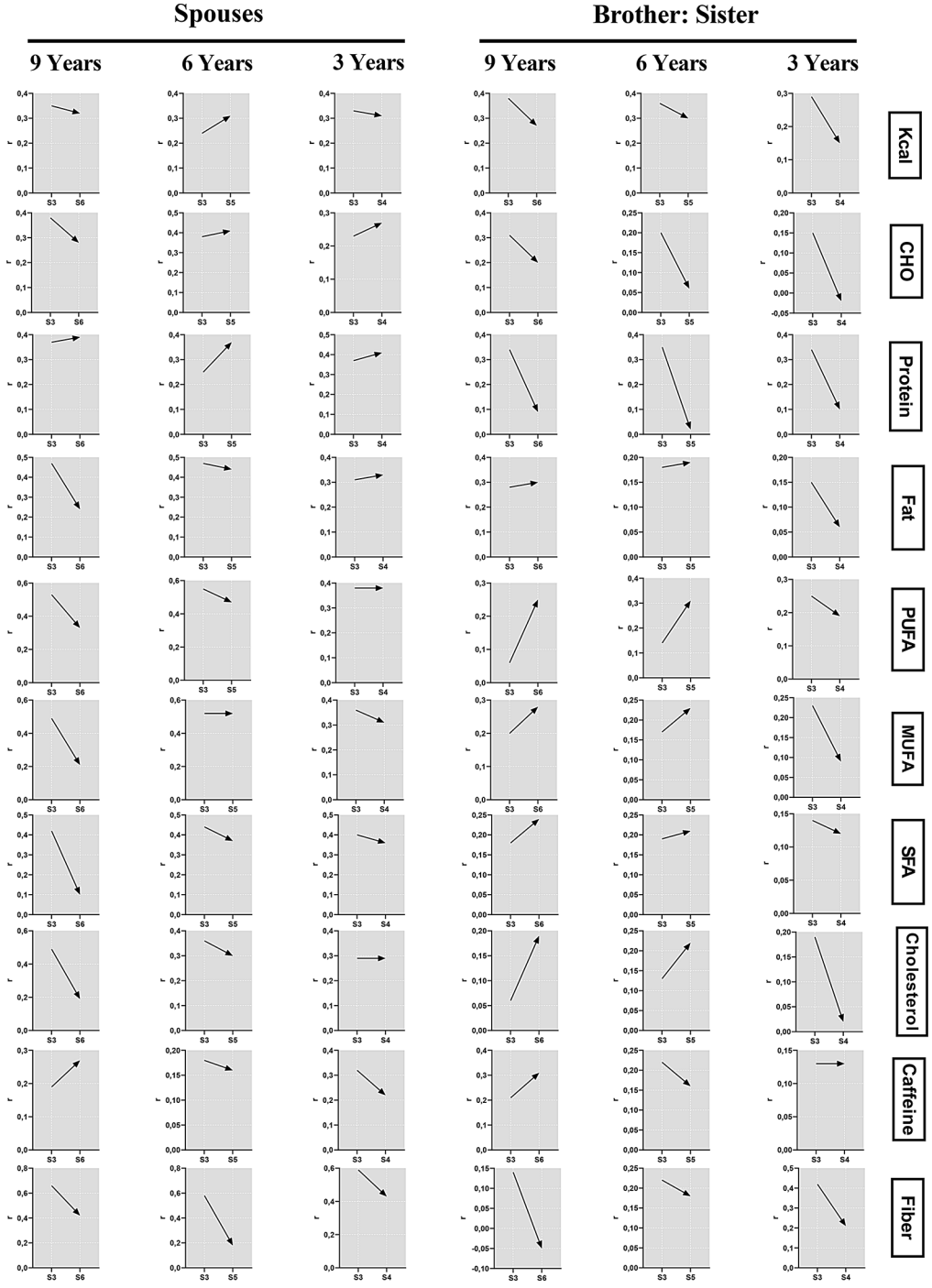


**Fig. 5** Changes in macronutrient correlations among brother-sister dyads and spouses over 3-year, 6-year, and 9-year follow-up periods

The sibling correlations provided further insights into the familial influences on dietary intake. In brother-sister dyads, the 3, 6, and 9-year analyses showed that correlation of carbohydrates, protein, and energy intake decreased over time, while there was an increasing correlation with fat (MUFA, PUFA, cholesterol, SFA, TF) intake, especially in the 6 and 9-year periods. The periodic 4-year analyses largely confirmed these findings, with decreasing correlations for energy, protein, and fiber intake, entirely due to gender differences. This was more influenced by stability in men's diets and changes in women's diets. Over time and with increasing age, women gain greater control over calorie intake and protein type, trying to consume beneficial foods such as fruits and vegetables, while men tend to maintain their calorie and nutrient intake [20, 21]. Interpreting the

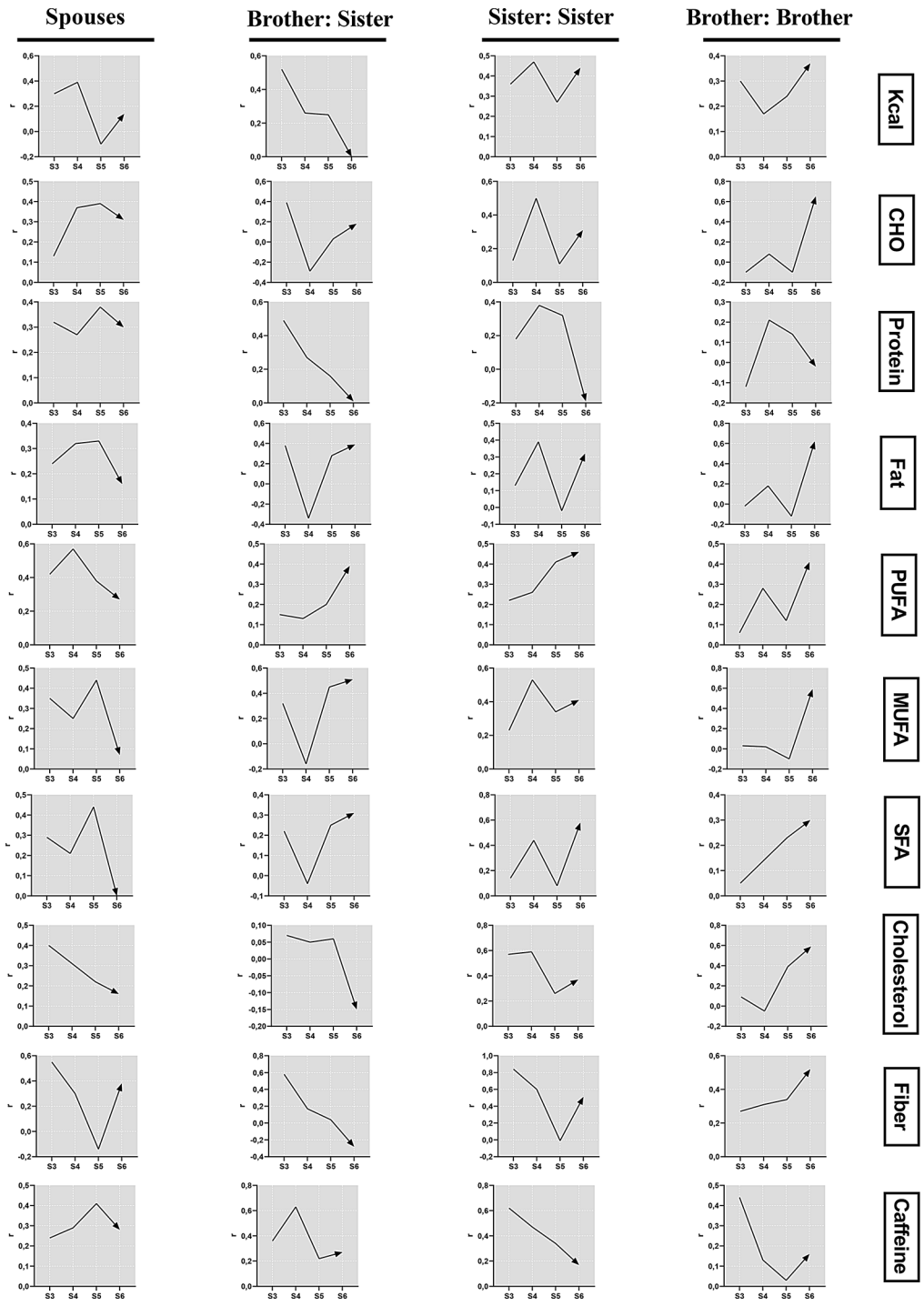


**Fig. 6** The correlation changes of macronutrients over a 9-year follow-up with four consecutive measurements in siblings and spouses

increased PUFA correlation is complicated due to the diversity of its food sources. This increase is more likely due to the increased consumption of vegetable oils in the last two decades among Iranians rather than consumption of PUFA's beneficial sources.

Over time, among sister-sister pairs, the correlation of protein and caffeine intake decreased. However, beneficial fats such as PUFA increased, while the rest did not exhibit a specific trend, depending on different times and locations. The increased PUFA correlation is due to the increased olive oil consumption among women in recent years in Iran. Regarding protein and caffeine, interpreting these variables is difficult due to the types of food items and their sources, as well as the effects of

changes in an individual's living environment on consumption of these substances. Our study lacked precise information about changes in the living conditions of individuals over time. For example, if one sister enters university and lives in a dormitory, she may consume more tea and coffee than a sister who remained at the parental home or have less access to protein sources compared to the sister living at the parental home. Similarly, for brother-brother pairs, where we observed increased correlation of macronutrients and calorie intake, we did not have data on whether brothers separated, married, pursued higher education in different locations, or experienced other significant life changes that could affect their shared environment. This absence of information makes it challenging to definitively attribute the observed increases in correlation to shared genetics, continued shared environment, or the influence of new family members. To address this limitation, we recommend that future cohort studies collect detailed data on participants' living arrangements, including when siblings live together and when they separate. It would be beneficial to track major life events, such as marriage or relocation for education or work, which could influence dietary patterns. Future research should assess the similarity of dietary intakes between siblings at different time points, particularly noting any changes when living situations change. Investigating how dietary patterns evolve when siblings live apart and the factors influencing these changes would provide valuable insights. Moreover, considering the inclusion of partners or spouses in the study could help examine the influence of new family members on dietary habits.

The observation of regression towards the mean patterns for certain macronutrient intake correlations in specific sibling dyads suggests the presence of shared genetic or environmental influences that shape dietary behaviors over time. However, the divergence from these patterns for other macronutrients highlights the role of additional factors, such as lifestyle changes, environmental exposures, and individual preferences, in differentially influencing dietary habits within sibling groups. Notably, the macronutrients exhibiting regression patterns varied across brother-brother, sister-sister, and brother-sister pairs, indicating potential gender-specific effects on dietary correlations. For instance, brother-brother pairs demonstrated consistent increases in SFA and fiber intake correlations, while sister-sister pairs exhibited an increase in PUFA intake correlation and a decrease in caffeine intake correlation. These findings underscore the complex interplay of genetic, environmental, and gender-specific factors in shaping long-term dietary behaviors and correlations within familial relationships, particularly among siblings.

In the current study among spouses, the correlation of cholesterol and different types of fats decreased over time. While genetic factors and hormonal variations contribute to these differences, societal expectations and cultural norms play an equally significant role in shaping eating behaviors [22]. Women, for instance, frequently encounter greater social pressure to maintain their health and appearance, especially as they age, which may lead them to adopt more conscientious eating habits [23, 24]. Men, in contrast, typically face less societal pressure to alter their diets, potentially resulting in higher fat consumption. Moreover, men often show a preference for high-fat meals, driven in part by the pleasure derived from consumption [25]. For the remaining macronutrients, there was a lot of fluctuation, however, for carbohydrates, an initially increasing correlation was observed, which then plateaued. This could be because the consumption of carbohydrate sources such as bread and rice is consistent in Iranian families [26]. Nevertheless, for other items such as caffeine intake or fiber from fruits and vegetables, the differences between husbands and wives are greater [27, 28], which is reflected in the fluctuations seen in the results. Overall, over time, the correlation of most food items among spouses decreases or reaches a plateau, whereas in the early years of marriage, these correlations were higher. This finding aligns with the concept of assortative mating, where individuals initially select partners with similar dietary preferences, leading to high correlations [29]. However, over time, shared environmental factors and potential lifestyle changes may contribute to the observed regression towards the population mean.

It is also noteworthy that the gender-specific trends observed across different familial relationships, particularly between parents and offspring and among spouses, highlight the complex interplay of sociocultural and environmental factors in shaping dietary behaviors. The stronger influence of maternal dietary habits on offspring nutrition, as well as the gender differences in spousal dietary correlations over time, reflect broader societal norms and expectations in Iranian culture. These patterns are likely influenced by factors such as traditional gender roles in food preparation, differing societal pressures on men and women regarding health and appearance, and gender-specific responses to nutritional education and health campaigns. Furthermore, the observed trends may be indicative of broader shifts in gender dynamics within Iranian families over the study period, reflecting changing social norms and economic roles. Understanding these gender-specific trends is crucial for developing targeted nutritional interventions and public health strategies that account for the unique influences on dietary behaviors within different familial relationships.

While our study provides valuable insights into familial dietary patterns over time, it is worth mentioning certain considerations that arose from the original design of the TLGS, which was not specifically intended for this analysis. For instance, we were unable to account for participants' marital status or changes in shared living environments across different study phases. These factors could significantly influence dietary similarities within families. Furthermore, the age variable presents a critical consideration for future research. Our categorizations (e.g., "sister-sister pairs") did not account for potentially large age differences between siblings, which could mask important distinctions in dietary patterns. Future studies should incorporate more nuanced age groupings and consider both genetic and environmental factors to provide a more comprehensive understanding of familial dietary correlations. Overall, our findings have important implications for public health interventions and nutritional counseling. The dynamic nature of familial dietary correlations over time suggests that interventions aimed at improving dietary habits should consider the evolving nature of familial influences. Moreover, the gender-specific patterns observed in our study indicate that tailored approaches may be necessary when addressing dietary behaviors within different familial contexts. Future research could further examine the underlying mechanisms driving the observed regression towards the mean pattern in macronutrient intake correlations, as well as the potential impact of specific familial dynamics, such as parenting styles, household composition, and shared activities, on dietary behaviors. Moreover, investigating the associations between familial correlations in macronutrient intake and health outcomes, such as obesity, cardiovascular disease, and metabolic disorders, could provide valuable insights into the development and prevention of chronic conditions.

One of the key strengths of this research was its comprehensive examination of how macronutrient intake correlations changed over time within different familial relationships (parent-child, siblings, spouses). Previous studies have often overlooked the impact of gender on these correlations. However, our findings demonstrated the importance of considering gender, as sister-sister pairs exhibited the highest number of increasing macronutrient intake correlations, while brother-sister pairs showed the highest number of decreasing correlations. The dietary data was collected through face-to-face interviews conducted by trained dietitians, which enhances the accuracy of measurements and reduces potential biases. Furthermore, the study employed various sample sizes, study designs, and four dietary assessments over a nine-year follow-up period. This approach allowed for a comprehensive understanding of changes in dietary habits and behaviors over time.

One limitation was the use of the USDA Food Composition Table, as the Iranian table is incomplete for certain food items. This may have led to measurement errors, such as overestimating macronutrient intake. However, if such a bias existed, it would have been consistent across all participants. While valid and reliable FFQs were used for dietary assessment, some degree of measurement bias is inevitable with this method. Although FFQs may have lower sensitivity in tracking small dietary changes over time, they remain the most cost-effective and suitable approach for large population cohorts. Due to missing data on participants' marital status, education, and occupation, adjustments for these potential confounders were not possible. Economic status data was also unavailable; however, since all participants were from the 13th district of Tehran, which has a relatively uniform medium-sized economic status, this limitation may be somewhat mitigated.

## Conclusions

In conclusion, this longitudinal study reveals distinct patterns in macronutrient intake correlations across different familial relationships over time. The observed tendency for initially divergent dietary habits to converge suggests a regression towards the mean phenomenon, indicating that dietary habits among family members tend to become more similar over time. This study highlights significant trends influenced by gender-specific dynamics, socialization processes, and shared environments. These findings emphasize the importance of adopting a family-centered approach in promoting healthy eating behaviors and preventing diet-related chronic diseases. Future interventions should account for the unique influences and environments within various familial settings to more effectively improve dietary habits and overall health outcomes.

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-20362-7.

Supplementary Material 1

**Acknowledgements**

This work was supported by a grant from the National Institute for Medical Research Development (NIMAD) (Project No. 4010276), Tehran, Iran. The authors would like to express their gratitude to the staff and participants in the TCGS project. This study was supported by Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

**Author contributions**

"Farshad Teymoori: Conceptualization, Writing-Original Draft, Methodology, Formal analysis. Niloufar Saber: Writing-Original Draft, Methodology, Formal analysis. Mahdi Akbarzadeh: Conceptualization, Writing-Original Draft, Formal analysis. Hossein Farhadnejad: Writing-Original Draft. Ebrahim Mokhtari: Writing-Original Draft. Parisa Riahi: Conceptualization, Formal analysis. Hamid

Ahmadirad: Writing-Original Draft. Parvin Mirmiran: Supervision. Maryam S Daneshpour: Supervision. Fereidoun Azizi: Supervision."

**Funding**
This work was supported by a grant from the National Institute for Medical Research Development (NIMAD) (Project No. 4010276), Tehran, Iran. The funding body has no role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

**Data availability**
The datasets generated and/or analyzed during the current study are not publicly available due to containing information that could compromise the privacy of research participants but are available from the corresponding author on reasonable request.

## Declarations

**Ethics approval and consent to participate**
Informed written consent was obtained from participants. All procedures performed in studies involving human participants adhered to the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study's protocol was approved by the ethics research committee of the National Institute for Medical Rsearch Develoapment (NIMAD), Tehran, Iran.

**Consent for publication**
Not applicable.

**Clinical trial number**
Not applicable.

**Competing interests**
The authors declare no competing interests.

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Received: 26 June 2024 / Accepted: 10 October 2024
Published online: 16 October 2024

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## Publisher's note