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Nutrition transition and nutrient inadequacy in Korea, 1998–2024: a national repeated cross-sectional trend study

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Research Article

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Abstract

Purpose

Korea has undergone rapid demographic, economic, and food-system change since the late 1990s. Although previous studies have described selected nutrient and dietary trends, long-term national evidence integrating nutrient intake, food-group intake, nutrient inadequacy, dietary excess, and diet-related behaviors through 2024 remains limited. This study examined longitudinal changes in adult nutrition in Korea using published national statistics based on the Korea National Health and Nutrition Examination Survey (KNHANES).

Methods

We conducted a national repeated cross-sectional trend study using publicly available aggregate nutrition tables from the Korea National Health Statistics and the official *Korea Health Statistics 2024* report. The primary analytic population comprised adults aged 19 years or older using published age-standardized estimates. Outcomes included energy and nutrient intake, macronutrient energy shares, food-group intake, nutrient insufficiency, energy excess, fat excess, sodium intake exceeding the chronic disease risk reduction threshold, fruit and vegetable intake of at least 500 g/day, healthy diet practices, breakfast skipping, eating out, and nutrition label use. First-to-last changes were summarized, and annual percentage changes (APCs) were estimated using weighted log-linear regression based on published standard errors.

Results

From 1998 to 2024, carbohydrate intake decreased from 323.5 to 253.0 g/day, whereas fat intake increased from 38.2 to 56.2 g/day. Carbohydrate energy share declined from 68.1% to 56.8%, while fat energy share increased from 16.6% to 26.6%. Sodium intake decreased from 4,951.2 to 3,279.6 mg/day; however, 68.4% of adults in 2024 remained above the chronic disease risk reduction threshold. Vitamin C intake declined by 51.0%, and iron intake declined by 28.0%. Food-group trends showed lower intake of grains, vegetables, fruits, and fish/shellfish, and markedly higher intake of beverages, meat, and dairy. Fruit and vegetable intake of at least 500 g/day decreased from 42.9% to 24.4%, while fat-excess intake increased from 23.8% to 34.4%. Nutrient insufficiency remained common, affecting 17.8% of adults in 2024.

Conclusions

Korea experienced a marked but mixed nutrition transition from 1998 to 2024. Lower carbohydrate and sodium intake were associated with higher exposure to total and saturated fat, displacement of several traditional nutrient-dense food groups, reduced fruit and vegetable adequacy, and persistent micronutrient vulnerability. These findings support nutrition policies that move beyond energy balance or sodium reduction alone and instead prioritize overall dietary quality, healthier fat profiles, fruit and vegetable intake, and micronutrient adequacy.

Introduction

Diet is a major determinant of population health because it links food environments, socioeconomic change, nutritional adequacy, and the risk of chronic disease. As countries modernize, dietary patterns often shift away from traditional staples toward greater intake of animal-source foods, fats, processed products, and convenience-oriented foods and beverages. This process, commonly described as the nutrition transition, does not necessarily produce uniform nutritional improvement. Instead, reductions in some traditional dietary risks may coexist with persistent micronutrient inadequacy, rising excess intake, and worsening diet quality [1-7].

Korea provides a particularly informative setting for examining this process. Since the late 1990s, the country has experienced rapid demographic aging, urbanization, rising household incomes, and substantial changes in the food system. During the same period, the Korea National Health and Nutrition Examination Survey (KNHANES) has provided nationally representative surveillance data on dietary intake, dietary behaviors, and nutritional status [1,2,4,5]. According to the official *Korea Health Statistics 2024* report, KNHANES estimates are based on complex sampling, weighted national estimation, and age-standardization to the 2005 Korean population for annual and socioeconomic trend comparisons. These characteristics make KNHANES especially valuable for long-term evaluation of national dietary change.

Previous Korean studies have already shown that carbohydrate intake has decreased while fat intake has increased over time, and that broader changes have occurred in food intake, sodium exposure, eating-out patterns, and selected micronutrient-related indicators [8-20]. However, most prior studies have focused on limited time periods, specific nutrients, selected foods, or particular behavioral outcomes. As a result, relatively little work has integrated nutrient intake, macronutrient energy distribution, food-group change, nutrient inadequacy, dietary excess, and diet-related behaviors into a single long-term national framework.

Such integration is important because the public-health meaning of dietary change depends on the level of analysis. A decline in sodium intake may indicate improvement, whereas a decline in fruit and vegetable intake may indicate worsening diet quality. Similarly, lower carbohydrate intake may reflect reduced dependence on grain-based staples. Still, it may also occur alongside greater exposure to fat and saturated fat, increased intake of meat and beverages, and persistent micronutrient vulnerability. Therefore, nutrition transition should not be interpreted from a single nutrient or a single summary indicator alone. The updated Korean national statistics through 2024 suggest that several dietary indicators are moving in different directions simultaneously, implying a mixed or multidimensional nutrition transition rather than uniformly favorable dietary modernization.

The present study addressed this gap by examining longitudinal changes in nutrient intake, food-group consumption, nutrient inadequacy, dietary excess, and diet-related behaviors among Korean adults from 1998 to 2024, using published data from the Korea National Health and Nutrition Examination Survey (KNHANES). By integrating age-standardized adult estimates across multiple nutrition domains, we aimed to provide a national repeated cross-sectional trend analysis with direct public-health and nutritional relevance. We hypothesized that Korea underwent a marked but mixed nutrition transition characterized by declining carbohydrate and sodium intake, increasing total and saturated fat exposure, displacement of traditional nutrient-dense food groups, worsening fruit and vegetable adequacy, and persistent micronutrient vulnerability.

Methodology

Study design and data source

This study was a national repeated cross-sectional trend analysis based on published aggregate statistics from the Korea National Health and Nutrition Examination Survey (KNHANES). KNHANES is a nationally representative surveillance system established to monitor the health and nutritional status of the Korean population and has been conducted since 1998 under the National Health Promotion Act [1,2]. It includes health interviews, health examinations, and nutrition surveys and has been widely used for national public health monitoring and nutrition research in Korea [1,2,4,5].

The present analysis used publicly available Korea National Health Statistics tables derived from the KNHANES rather than individual-level raw microdata. The main source materials were updated official workbooks covering nutrient intake, food-group intake, nutrient inadequacy and excess, and diet-related behaviors through 2024. These data were interpreted together with the official *Korea Health Statistics 2024* report, which documents the sampling design, weighting procedures, standardization framework, and survey-cycle changes used in producing the published national estimates. According to the official report, all published results are presented as weighted sample means or weighted proportions, and annual and socioeconomic trend estimates are age-standardized to the 2005 Korean population to improve comparability across time.

Because this study analyzed published surveillance estimates rather than original participant-level observations, the findings should be interpreted as population-level national trends rather than individual-level associations.

Survey cycles and methodological context

KNHANES was initiated in 1998 and subsequently conducted in repeated survey cycles, including KNHANES I (1998), II (2001), III (2005), IV (2007–2009), V (2010–2012), VI (2013–2015), VII (2016–2018), VIII (2019–2021), and IX (2022–2024) [1,2]. The 2024 official report corresponds to KNHANES IX-3, conducted from January to December 2024. The survey-cycle structure and the major methodological issues relevant to long-term interpretation are summarized in Table 1.

The official 2024 report notes several issues relevant to trend interpretation. Published estimates may differ from those in earlier reports due to weight adjustments, variance-stratum integration, data corrections, updated population projections, and revised estimation procedures. In addition, beginning in 2022, the nutrition survey protocol changed in ways that may affect comparability, including changes in the survey setting and the dietary recall reference day. These methodological issues were considered when interpreting long-term patterns and especially recent-period changes spanning 2022–2024.

Study population

The primary analytic population comprised adults aged 19 years or older. Main analyses were based on the published age-standardized adult estimates, which were selected to improve comparability over time amid marked population aging in Korea. The official Korea Health Statistics report states that annual and socioeconomic comparisons are age-standardized using the 2005 Korean population, making these estimates the most appropriate basis for long-term national trend analysis.

Although total-population and subgroup estimates were also available in the source files, the present manuscript focuses on adult age-standardized trends as the principal analytic set. Sex-, age-, and income-specific estimates were retained for secondary and future analyses but were not treated as the primary framework in this manuscript.

Outcome variables

To capture the multidimensional nature of nutrition transition, we examined four broad outcome domains: nutrient intake, macronutrient energy distribution, food-group intake, and nutrient inadequacy/excess and diet-related behaviors. The complete analytic framework is summarized in Table 2.

The nutrient intake outcomes included total energy, carbohydrate, protein, total fat, saturated fat, sodium, calcium, iron, vitamin C, and vitamin D. Macronutrient energy distribution outcomes included the percentages of total energy derived from carbohydrate, protein, and fat. Food-group outcomes included grain, vegetable, fruit, beverage, meat, fish and shellfish, and milk and dairy intake. Nutrient inadequacy and excess outcomes included nutrient insufficiency, energy excess, fat excess, sodium intake above the chronic disease risk-reduction threshold, fruit and vegetable intake of at least 500 g/day, and healthy diet practices. Diet-related behavior outcomes included skipping breakfast, eating out at least once per day, and using nutrition labels.

These outcomes were selected because they jointly capture both favorable and unfavorable aspects of dietary change and therefore allow a more complete interpretation of national nutrition transition than any single nutrient or behavioral indicator alone.

Data extraction and quality control

The official workbook files were transformed into a long-format analytic dataset using a reproducible extraction workflow. The extraction process identified year labels, indicator names, subgroup labels, estimate values, and standard errors across the nutrient, food-group, inadequacy/excess, and behavior domains. Numeric values were cleaned by standardizing year labels, removing formatting characters, and aligning estimate–standard error pairs.

Quality-control procedures included removal of duplicate parsed records, verification of year continuity, and cross-checking of first and latest values against the original table structures for key indicators such as carbohydrate intake, fat intake, sodium intake, vitamin C intake, fruit intake, fruit and vegetable adequacy, and fat-excess prevalence. Updated project files included summary datasets for adult standardized nutrient change, adult standardized inadequacy change, long-format trend data, and trend model outputs, which formed the basis for the manuscript tables and figures.

Statistical analysis

The primary objective of the analysis was to quantify the direction, magnitude, and temporal pattern of long-term national dietary change.

First, each indicator was summarized using:

- first available year,
- first available value,
- latest available year,
- latest value,
- absolute change,
- relative percentage change.

For prevalence-type indicators, absolute differences were interpreted as percentage-point changes.

Second, annual percentage changes (APCs) were estimated for major indicators using weighted log-linear regression models. In these models, the natural logarithm of the published estimate was regressed on survey year. When standard errors were available from the official tables, inverse-variance weights were approximated using the delta method for log-transformed outcomes. APCs and 95% confidence intervals were then derived from the fitted slope coefficients and their standard errors. This approach provided annualized estimates of trend direction and magnitude while accounting for the fact that the analysis was based on already-weighted national surveillance statistics rather than raw participant-level data. The updated manuscript draft identifies APC modeling as the principal trend-quantification strategy in the current version of the paper.

Third, period-specific absolute changes were calculated to characterize major phases of transition. Where data availability allowed, changes were summarized across three periods: 1998–2010, 2010–2019, and 2019–2024. The final period was considered especially important because it spans the COVID-19 pandemic and its aftermath. This period-based framework was used to supplement overall APC estimates and to determine whether recent dietary shifts differed from earlier long-term patterns.

Because this study used published weighted national estimates, the statistical models describe trends in reported surveillance statistics rather than estimating individual-level associations. Thus, the analysis supports population-level trend interpretation but does not permit causal inference, adjustment for individual-level covariates, or direct estimation of within-person dietary inadequacy. Those questions would require raw KNHANES microdata and full complex-sample regression modeling.

Interpretation framework

A key feature of this study was the integrated interpretation of nutrient intake, food-group change, nutrient inadequacy, excess intake, and behavior. Rather than interpreting change through a single nutrient alone, the analysis explicitly treated Korea’s dietary evolution as a multidimensional nutrition transition. This framework was adopted because lower sodium and carbohydrate intake, higher fat intake, declining fruit and vegetable adequacy, and persistent nutrient insufficiency may occur simultaneously and have distinct public health implications. The study therefore emphasized a mixed or divergent nutrition transition rather than assuming that all long-term dietary change reflected improvement.

Ethical considerations

This study used publicly reported aggregate national statistics and did not involve identifiable individual-level data. As such, individual informed consent was not required for this secondary analysis. Institutional review requirements for the final manuscript should be determined in accordance with the policy of the submitting institution. Still, the current analysis falls within the scope of secondary use of publicly available aggregated statistics. The official KNHANES system is conducted as a nationally mandated survey, and the 2024 report documents its status as a designated national statistic under Korean law.

Results

Macronutrient redistribution

A marked redistribution of macronutrient intake was observed among Korean adults between 1998 and 2024. Carbohydrate intake decreased from 323.5 g/day in 1998 to 253.0 g/day in 2024, representing an absolute decline of 70.5 g/day and a relative decrease of 21.8%. In contrast, total fat intake increased from 38.2 to 56.2 g/day, corresponding to an absolute increase of 18.0 g/day and a relative increase of 47.1%. Protein intake changed little over the same period, from 76.1 to 75.7 g/day. APC models showed a significant annual decline in carbohydrate intake and a significant annual increase in fat intake, whereas protein intake remained essentially stable. Saturated fat intake, available from 2013 onward, increased from 14.2 to 17.7 g/day, indicating that the increase in fat exposure was accompanied by a less favorable shift in fat quality. These results indicate that the Korean diet shifted from a traditionally carbohydrate-dominant pattern toward a more fat-intensive profile.

Macronutrient energy shares further clarified this transition. The contribution of carbohydrate to total energy intake declined from 68.1% in 1998 to 56.8% in 2024, whereas the contribution of fat increased from 16.6% to 26.6%. Protein energy share increased modestly. Thus, the transition was not limited to changes in gram-level intake alone but reflected a substantial redistribution of dietary energy across macronutrients. In practical terms, the national dietary pattern of Korean adults became less carbohydrate-centered and progressively more fat-oriented over the study period.

Sodium and selected micronutrient trends

Sodium intake showed the clearest favorable long-term trend. Mean intake declined from 4,951.2 mg/day in 1998 to 3,279.6 mg/day in 2024, corresponding to an absolute reduction of 1,671.6 mg/day and a relative decrease of 33.8%. The APC was consistently negative, indicating sustained long-term decline. However, this improvement did not translate into adequate sodium control at the population level. According to the updated 2024 analysis, 68.4% of adults still exceeded the chronic disease risk-reduction threshold for sodium intake, indicating that sodium excess remains a major unresolved public health issue despite substantial improvement over time.

In contrast to sodium, several micronutrients showed unfavorable trends. Vitamin C intake declined from 130.3 mg/day in 1998 to 63.9 mg/day in 2024, a reduction of 66.4 mg/day (51.0%). Iron intake also declined from 13.2 to 9.5 mg/day, representing a 28.0% reduction. Vitamin D intake remained persistently low and decreased slightly from 3.6 μg/day in 2016 to 3.3 μg/day in 2024. Calcium intake showed little net change across the full study period, remaining near 500 mg/day. Together, these findings indicate that the nutrition transition did not result in uniform improvements in micronutrient status and that certain aspects of micronutrient adequacy may have worsened over time.

Food-group transition

Food-group trends provided the clearest explanation for the observed nutrient patterns. Grain intake declined from 342.0 g/day in 1998 to 253.8 g/day in 2024, a relative decrease of 25.8%. Vegetable intake declined from 325.5 to 263.9 g/day, while fruit intake declined more sharply, from 200.3 to 114.4 g/day, representing a 42.9% reduction. Fish and shellfish intake also decreased substantially, from 72.3 to 47.0 g/day. These findings indicate reduced intake of several traditional or nutrient-dense food groups over time.

By contrast, marked increases were observed in several food groups associated with dietary modernization. Beverage intake increased from 46.6 g/day in 1998 to 316.5 g/day in 2024, corresponding to a 579.2% increase. Meat intake rose from 70.8 to 136.8 g/day, nearly doubling over the study period, and milk and dairy intake increased from 49.2 to 92.6 g/day. These opposing patterns indicate that the Korean nutrition transition was

characterized not only by a decline in traditional staple and plant-based food groups but also by a shift toward beverages, meat, and dairy products. This shift provides a plausible explanation for the observed decline in carbohydrate intake, the rise in exposure to fat and saturated fat, and the worsening of fruit-related micronutrient indicators.

Nutrient inadequacy, dietary excess, and diet quality

Changes in nutrient inadequacy and excess revealed a mixed pattern. Nutrient insufficiency affected 19.5% of adults in 1998 and 17.8% in 2024, indicating only modest net improvement over 26 years. In contrast, fat excess increased substantially, from 23.8% in 2005 to 34.4% in 2024. Energy excess changed comparatively little, increasing from 13.9% to 14.9% over the same period. Thus, while overall nutrient insufficiency did not worsen dramatically, excess fat intake became substantially more common.

Diet-quality indicators showed a similarly divergent pattern. The proportion of adults consuming at least 500 g/day of fruits and vegetables declined sharply from 42.9% in 1998 to 24.4% in 2024, a decrease of 18.5 percentage points. This was one of the most notable deteriorations among the food-based indicators and was consistent with the large declines observed in fruit and vegetable intake. In contrast, the healthy diet practice indicator increased from 27.8% in 2005 to 50.5% in 2024. Nutrition-label use also increased substantially, whereas breakfast skipping nearly doubled over the long term, from 19.8% in 2001 to 38.9% in 2024. These findings suggest that improvements in awareness-oriented or composite indicators may coexist with deterioration in concrete food-based adequacy and meal-pattern behavior.

Recent changes in the 2019–2024 period

The period from 2019 to 2024 showed several noteworthy departures from the broader long-term pattern. Carbohydrate intake declined further during this period, whereas fat intake continued to increase. Fruit and vegetable adequacy continued to worsen, and fat excess continued to rise. Breakfast skipping increased further, while the proportion eating out at least once per day decreased. These recent changes likely reflect not only the continuation of the earlier dietary transition but also the disruption associated with the COVID-19 pandemic and the post-pandemic period. Because the official 2024 report notes methodological changes to the nutrition survey beginning in 2022, these recent estimates should be interpreted with caution as surveillance signals rather than purely behavioral shifts.

Integrated interpretation of the national transition

Taken together, the results indicate that Korea underwent a multidimensional nutrition transition rather than a uniformly favorable dietary improvement. Some indicators improved, most notably sodium intake, while other indicators worsened, including total fat intake, saturated fat intake, fruit and vegetable adequacy, fat excess, and several selected micronutrients. Food-group analysis showed a concurrent decline in grains, vegetables, fruits, and fish/shellfish and an expansion of beverages, meat, and dairy products. The overall pattern, therefore, reflects a mixed transition in which reductions in some traditional dietary risks were accompanied by increased exposure to other nutrition-related vulnerabilities.

Discussion

This national repeated cross-sectional trend study shows that Korea underwent a multidimensional nutrition transition between 1998 and 2024. The transition was not uniformly favorable. On the one hand, carbohydrate intake and sodium intake declined substantially. On the other hand, total fat and saturated fat exposure increased, fruit and vegetable adequacy deteriorated, fat-excess intake became more common, and several micronutrients remained low or declined over time. Food-group results reinforced this interpretation by showing simultaneous declines in grains, fruits, vegetables, and fish/shellfish, along with marked increases in beverage, meat, and dairy intake. Taken together, these findings indicate that the Korean nutrition transition is best understood not as a simple improvement in diet, but as a mixed transition involving both progress and new forms of nutritional vulnerability.

The macronutrient findings are consistent with earlier Korean studies that reported a long-term decline in carbohydrate intake and an increase in fat intake [8–10]. However, the present study extends that evidence in several important ways. First, it updates the national record through 2024. Second, it shows that the gram-level shift was also an energy-distribution shift, with carbohydrate energy share decreasing and fat energy share increasing over time. Third, it links these changes to food-group substitution, indicating that reduced grain intake was accompanied by increased intake of meat, dairy, and especially beverages. This broader framing matters because a decline in carbohydrate intake might otherwise be interpreted as inherently beneficial. Our results suggest that such an interpretation would be incomplete. Lower carbohydrate intake in Korea was accompanied by a less favorable fat profile and worsening plant-food adequacy, meaning that the direction of change cannot be judged from carbohydrate decline alone.

The food-group findings provide important explanatory context for the nutrient trends. Grain intake declined substantially, which likely accounts for much of the reduction in carbohydrate intake. At the same time, meat and dairy intake increased, offering a plausible explanation for the increase in total fat and saturated fat intake. The very large rise in beverage intake is especially notable. It likely reflects broader changes in the food environment, including greater availability of packaged beverages, sweetened drinks, and coffee-based beverages, as well as more convenience-oriented consumption. Meanwhile, the decline in fruit and vegetable intake provides a plausible explanation for the sharp decline in vitamin C intake and the rising prevalence of inadequate fruit and vegetable consumption. These linked trends suggest that the Korean nutrition transition involved not only nutrient redistribution, but also a substantial reorganization of the national food pattern.

Sodium deserves special attention because it represents both a success story and a continuing problem. The long-term reduction in sodium intake is one of the clearest favorable findings in the national nutrition record. This decline may reflect sodium-reduction campaigns, product reformulation, changes in cooking practices, changes in fermented-food consumption, and greater nutrition awareness. However, the public-health significance of this improvement should not be overstated. In 2024, more than two-thirds of adults still exceeded the chronic disease risk reduction threshold for sodium. Thus, Korea appears to have made meaningful progress in sodium reduction, but not enough to conclude that sodium is no longer a major dietary risk. The policy implication is that sodium reduction should continue, but within a broader strategy focused on overall dietary quality rather than a single-nutrient approach.

The micronutrient findings are among the most concerning aspects of the analysis. Vitamin C intake declined by approximately half over the study period; iron intake also fell substantially, vitamin D intake remained persistently low, and calcium intake showed little meaningful improvement. These results suggest that long-term dietary modernization in Korea did not produce a broad improvement in nutrient adequacy. Instead, some traditional

excess-related concerns now coexist with persistent or emerging micronutrient vulnerability. This pattern is consistent with the nutrition-transition literature, which emphasizes that overweight, excess intake, and micronutrient inadequacy can coexist within the same population [6, 7]. In the Korean context, that coexistence appears to be occurring within a high-income national setting, where dietary abundance in some domains does not guarantee adequate dietary quality in others.

One of the most important findings is the persistence of nutrient insufficiency despite major dietary change. Nutrient insufficiency declined only modestly over the full study period and remained common in 2024. This suggests that the transition in Korea has not resolved underlying nutritional vulnerability. At the same time, fat excess rose substantially, and fruit and vegetable adequacy declined sharply. These results support a dual-burden interpretation of Korean dietary change. Some elements of the traditional dietary risk profile have improved, but new excess-related and quality-related problems have become more prominent. In contrast, older inadequacy-related problems have not fully disappeared. This is arguably the central public-health contribution of the study.

The divergence between composite and component indicators is also important. Healthy dietary practices increased over time, and use of nutrition labels also rose markedly, suggesting greater awareness of healthy eating or greater exposure to nutrition policy and education. Yet this did not prevent worsening fruit and vegetable adequacy, increasing breakfast skipping, or persistent nutrient insufficiency. This mismatch suggests that awareness-oriented indicators and composite behavioral measures may not fully capture actual nutrient adequacy or food-pattern quality. In other words, improvements in reported healthy practices do not necessarily guarantee improvement in the nutritional structure of the diet. This has implications for both surveillance and intervention design: policymakers should avoid assuming that better knowledge or better composite scores automatically translate into adequate intake of nutrient-dense foods.

The period from 2019 to 2024 warrants special consideration. During this period, breakfast skipping increased further, daily eating out decreased, and fruit and vegetable adequacy continued to decline. These shifts likely reflect a combination of longer-term transition and more recent disruption associated with the COVID-19 and post-pandemic period. However, the official 2024 report also documents methodological changes introduced beginning in 2022, including changes in the nutrition survey setting and the recall reference day. Therefore, the most recent period should be interpreted cautiously. The observed changes are highly relevant as surveillance signals, but they cannot be assumed to represent purely behavioral shifts without considering possible methodological influence.

This study has several strengths. First, it used a long national observation window spanning 26 years. Second, it relied on nationally representative published statistics produced within the official KNHANES framework. Third, it focused on age-standardized adult estimates to improve comparability amid rapid population aging. Fourth, it integrated multiple data domains—nutrient intake, energy distribution, food-group intake, inadequacy, excess, and behavior into a single analytic framework. Fifth, it estimated annual percentage changes and recent-period changes rather than relying only on first-to-last comparisons. Together, these features make the study stronger than a conventional descriptive nutrient-trend paper and allow it to serve as a national nutrition surveillance paper with clearer public health interpretation.

Several limitations should also be acknowledged. First, this analysis used published aggregate tables rather than raw KNHANES microdata. Therefore, the results support the interpretation of population-level surveillance but do not allow individual-level causal inference. For example, the study cannot determine whether people with lower

fruit intake had lower vitamin C intake, whether breakfast skipping predicts nutrient inadequacy, or whether income differences explain the observed national trends. Second, long-term comparability may be affected by changes in dietary reference standards, food composition databases, survey instruments, and estimation procedures across survey cycles. Third, the nutrition survey changes introduced in 2022 may have influenced intake and behavior estimates in the most recent years. Fourth, one-day dietary intake data have inherent limitations when used to evaluate usual intake or true prevalence of nutrient inadequacy. Therefore, insufficiency and excess indicators should be interpreted as surveillance markers rather than definitive clinical measures of individual nutritional status. Fifth, although the present APC models provide useful annualized trend estimates, formal joinpoint regression could further improve the identification of inflection points. It should be considered in the subsequent refinement of the paper.

Future research should extend this work by using raw KNHANES microdata and conducting a full complex-sample analysis. That would allow more precise estimation of subgroup disparities by sex, age, income, and household food security, and enable stronger modeling of relationships among dietary behaviors, food groups, nutrient adequacy, and excess intake. Additional analyses should also examine nutrient-source patterns and food-group contributions in greater detail, especially for sodium, saturated fat, vitamin C, calcium, and vitamin D. Finally, future work should evaluate whether the post-2019 changes observed here represent a temporary disruption, a methodological discontinuity, or a durable new phase in the Korean dietary transition.

Conclusion

In conclusion, Korea underwent a major nutrition transition between 1998 and 2024, but it did not yield uniformly favorable nutritional outcomes. Lower carbohydrate and sodium intake were accompanied by greater exposure to fat and saturated fat, the displacement of several traditional nutrient-dense food groups, a worsening of fruit and vegetable adequacy, and persistent nutrient insufficiency. These findings indicate that future nutrition policy in Korea should move beyond a narrow focus on energy balance or sodium reduction alone and instead prioritize overall dietary quality, fruit and vegetable intake, healthier fat profiles, and micronutrient adequacy.

Between 1998 and 2024, Korean adults underwent a substantial nutrition transition, shifting away from a traditionally high-carbohydrate dietary pattern toward greater total and saturated fat intake. Although sodium intake declined markedly over time, sodium excess remained highly prevalent. At the same time, fruit and vegetable adequacy worsened, several micronutrient indicators remained low or declined, and nutrient insufficiency persisted in a considerable proportion of adults. Food-group trends further showed declines in intake of grains, fruits, vegetables, and fish and shellfish, alongside increases in intake of beverages, meat, and dairy products.

Taken together, these findings indicate that Korea’s dietary transition was not uniformly favorable. Instead, it reflected a mixed pattern in which improvement in some indicators coexisted with persistent or emerging nutritional vulnerability. Future national nutrition policy should therefore move beyond focusing on energy intake or sodium reduction alone and place greater emphasis on dietary quality, fruit and vegetable intake, healthier fat profiles, and micronutrient adequacy.

Declarations

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Author Contribution

R.K.M.A.D. conceived and designed the study, collected and curated the data sources, performed the statistical analysis, interpreted the findings, prepared Figures 1–6 and Tables 1–6, wrote the original manuscript draft, and reviewed and approved the final manuscript.

Data Availability

The data used in this study are publicly available aggregated statistics from the Korea National Health Statistics based on the Korea National Health and Nutrition Examination Survey (KNHANES), provided by the Korea Disease Control and Prevention Agency through the Korean Public Data Portal and documented in Korea Health Statistics 2024. This study used published aggregate estimates rather than individual-level raw microdata. Derived analytic files are available from the corresponding author upon reasonable request.

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Tables

Table 1. Survey cycles and methodological context of the KNHANES used in this study

Survey cycle	Calendar years	Survey structure	Relevance to the present study	Methodological notes
KNHANES I	1998	National cross-sectional survey	Earliest baseline for long-term trend analysis	First national baseline used in the study
KNHANES II	2001	National cross-sectional survey	Early transition period	Supports comparison after 1998
KNHANES III	2005	National cross-sectional survey	Pre-annual survey transition benchmark	Important anchor year before continuous annual surveys
KNHANES IV	2007–2009	Annual survey within a 3-year cycle	Start of the continuous annual surveillance era	Improved temporal continuity for trend analysis
KNHANES V	2010–2012	Annual survey within a 3-year cycle	Mid-transition phase	Supports comparison before later dietary pattern shifts
KNHANES VI	2013–2015	Annual survey within a 3-year cycle	Recent pre-pandemic transition phase	Includes later indicators such as saturated fat
KNHANES VII	2016–2018	Annual survey within a 3-year cycle	Late pre-pandemic comparison period	Useful for identifying recent acceleration or slowing of trends
KNHANES VIII	2019–2021	Annual survey within a 3-year cycle	Pandemic transition period	Important for interpreting behavior and intake changes during COVID-19
KNHANES IX	2022–2024	Annual survey within a 3-year cycle	Most recent period and current endpoint	Includes updated 2024 national estimates and survey-procedure changes

Table footnote: KNHANES is a nationally representative survey using complex sampling and survey weights. Published annual and socioeconomic estimates are presented as weighted means or weighted proportions and are age-standardized to the 2005 Korean population for trend comparison. The official 2024 report notes that changes in weighting, variance estimation, population projections, food composition tables, dietary reference standards, and nutrition survey procedures may affect comparability across cycles.

Table 2. Main study outcomes and analytic domains

Analytic domain	Outcome variable	Unit	Interpretation	Role in the manuscript
Energy intake	Total energy intake	kcal/day	Overall calorie exposure	General nutrition trend
Macronutrient intake	Carbohydrate intake	g/day	Traditional staple-based dietary component	Core transition indicator
Macronutrient intake	Protein intake	g/day	Protein exposure	Supporting transition indicator
Macronutrient intake	Total fat intake	g/day	Fat exposure	Core transition indicator
Macronutrient intake	Saturated fat intake	g/day	Less favorable fat-quality indicator	Risk-oriented transition marker
Macronutrient energy distribution	Carbohydrate energy share	% of energy	Relative contribution of carbohydrate	Energy redistribution indicator
Macronutrient energy distribution	Protein energy share	% of energy	Relative contribution of protein	Energy redistribution indicator
Macronutrient energy distribution	Fat energy share	% of energy	Relative contribution of fat	Energy redistribution indicator
Micronutrient intake	Sodium intake	mg/day	Sodium burden	Public health improvement/risk indicator
Micronutrient intake	Calcium intake	mg/day	Bone-related nutrient adequacy	Persistent adequacy concern
Micronutrient intake	Iron intake	mg/day	Essential micronutrient adequacy	Vulnerability indicator
Micronutrient intake	Vitamin C intake	mg/day	Fruit/vegetable-linked micronutrient	Diet-quality indicator
Micronutrient intake	Vitamin D intake	μg/day	Low-intake micronutrient	Persistent adequacy concern
Food-group intake	Grain intake	g/day	Traditional staple food intake	Food-pattern transition indicator
Food-group intake	Vegetable intake	g/day	Plant-food quality component	Food-pattern transition indicator
Food-group intake	Fruit intake	g/day	Plant-food quality component	Food-pattern transition indicator
Food-group intake	Beverage intake	g/day	Modern/convenience dietary shift marker	Food-pattern transition indicator
Food-group intake	Meat intake	g/day	Animal-source food transition marker	Food-pattern transition indicator
Food-group intake	Fish and shellfish intake	g/day	Traditional protein-source component	Food-pattern transition indicator

Food-group intake	Milk and dairy intake	g/day	Animal-source/modern diet marker	Food-pattern transition indicator
Inadequacy and excess	Nutrient insufficiency	%	Overall inadequacy burden	Core public health indicator
Inadequacy and excess	Energy excess	%	Overconsumption indicator	Dual-burden indicator
Inadequacy and excess	Fat excess	%	High-fat diet indicator	Dual-burden indicator
Inadequacy and excess	Sodium above the chronic disease risk reduction threshold	%	Excess sodium-risk prevalence	Sodium policy indicator
Diet quality	Fruit and vegetable intake of at least 500 g/day	%	Food-based diet-quality adequacy	Key quality indicator
Diet quality	Healthy diet practice	%	Composite healthy-diet behavior indicator	Supportive quality indicator
Dietary behavior	Breakfast skipping	%	Meal-pattern behavior	Behavioral context
Dietary behavior	Eating out at least once per day	%	Food environment/meal location behavior	Behavioral context
Dietary behavior	Nutrition-label use	%	Diet-related awareness/decision behavior	Behavioral context

Table 3. Nutrient and macronutrient energy-share trends among Korean adults, 1998–2024

Indicator	Unit	First year	First value	Latest year	Latest value	Absolute change	Relative change (%)	APC % (95% CI)	Change, 2019–2024
Energy intake	kcal/day	1998	1,967.1	2024	1,911.9	-55.2	-2.8	-0.10 (-0.39 to 0.19)	-92.8
Carbohydrate intake	g/day	1998	323.5	2024	253.0	-70.5	-21.8	-0.94 (-1.29 to -0.58)	-25.2
Protein intake	g/day	1998	76.1	2024	75.7	-0.4	-0.5	0.00 (-0.21 to 0.21)	0.2
Fat intake	g/day	1998	38.2	2024	56.2	18.0	47.1	1.57 (1.27 to 1.88)	3.6
Saturated fat intake	g/day	2013	14.2	2024	17.7	3.6	25.4	2.06 (1.48 to 2.65)	0.7
Carbohydrate energy share	% of energy	1998	68.1	2024	56.8	-11.3	-16.6	-0.66 (-0.81 to -0.50)	-3.6
Fat energy share	% of energy	1998	16.6	2024	26.6	10.0	60.2	2.00 (1.73 to 2.28)	2.9
Sodium intake	mg/day	1998	4,951.2	2024	3,279.6	-1,671.6	-33.8	-2.61 (-3.12 to -2.09)	-176.0
Calcium intake	mg/day	1998	503.7	2024	499.0	-4.7	-0.9	-0.19 (-0.42 to 0.03)	6.9
Iron intake	mg/day	1998	13.2	2024	9.5	-3.7	-28.0	-2.11 (-3.09 to -1.11)	-0.3
Vitamin C intake	mg/day	1998	130.3	2024	63.9	-66.4	-51.0	-3.30 (-4.03 to -2.56)	-3.8
Vitamin D intake	µg/day	2016	3.6	2024	3.3	-0.3	-8.3	-2.76 (-3.70 to -1.81)	0.1

Table 4. Food-group intake trends among Korean adults, 1998–2024

Indicator	Unit	First year	First value	Latest year	Latest value	Absolute change	Relative change (%)	APC % (95% CI)	Change, 2019–2024
Grain intake	g/day	1998	342.0	2024	253.8	-88.2	-25.8	-0.87 (-1.14 to -0.59)	-20.5
Vegetable intake	g/day	1998	325.5	2024	263.9	-61.6	-18.9	-1.24 (-1.56 to -0.91)	-19.6
Fruit intake	g/day	1998	200.3	2024	114.4	-85.9	-42.9	-1.99 (-3.03 to -0.93)	-26.2
Beverage intake	g/day	1998	46.6	2024	316.5	269.9	579.2	8.05 (7.01 to 9.11)	69.8
Meat intake	g/day	1998	70.8	2024	136.8	66.0	93.2	2.22 (1.88 to 2.55)	11.6
Fish and shellfish intake	g/day	1998	72.3	2024	47.0	-25.3	-35.0	-2.12 (-2.48 to -1.75)	-2.6
Milk and dairy intake	g/day	1998	49.2	2024	92.6	43.4	88.2	2.46 (1.82 to 3.11)	6.0

Table 5. Nutrient inadequacy, dietary excess, and diet-related behavior trends among Korean adults, 1998–2024

Indicator	Unit	First year	First value	Latest year	Latest value	Absolute change	Relative change (%)	APC % (95% CI)	Change, 2019–2024
Nutrient insufficiency	%	1998	19.5	2024	17.8	-1.7	-8.7	0.34 (-1.09 to 1.80)	-0.5
Energy excess	%	1998	13.9	2024	14.9	1.0	7.2	0.21 (-1.06 to 1.49)	-2.6
Fat excess	%	2005	23.8	2024	34.4	10.6	44.5	1.82 (0.29 to 3.37)	11.1
Sodium above the chronic disease risk reduction threshold	%	2022	66.9	2024	68.4	1.5	2.2	1.11 (1.02 to 1.20)	1.5
Fruit and vegetable intake of at least 500 g/day	%	1998	42.9	2024	24.4	-18.5	-43.1	-2.00 (-2.72 to -1.28)	-7.0
Healthy diet practice	%	2005	27.8	2024	50.5	22.7	81.7	3.32 (2.86 to 3.79)	3.6
Breakfast skipping	%	2001	19.8	2024	38.9	19.1	96.5	3.34 (2.94 to 3.74)	4.8
Eating out at least once per day	%	2008	24.7	2024	24.8	0.1	0.4	-0.63 (-1.94 to 0.70)	-6.2
Nutrition-label use	%	2005	23.1	2024	43.1	20.0	86.6	3.45 (2.90 to 4.00)	9.6

Table 6. Analytic contribution of each data domain

Domain	Main variables	Scientific contribution
Nutrient intake	Energy, macronutrients, sodium, micronutrients	Quantifies nutrient-level transition and adequacy concerns
Macronutrient energy distribution	Carbohydrate, protein, and fat percentages of energy	Shows redistribution of dietary energy beyond the gram-level changes
Food groups	Grains, vegetables, fruits, beverages, meat, fish/shellfish, dairy	Links nutrient changes to concrete food-pattern substitutions
Inadequacy and excess	Nutrient insufficiency, fat excess, sodium above the chronic disease risk reduction threshold, and fruit and vegetable intake of at least 500 g/day	Shows whether the transition improved or worsened dietary quality
Dietary behavior	Breakfast skipping, eating out, and nutrition-label use	Provides behavioral context for recent and long-term changes

Figures

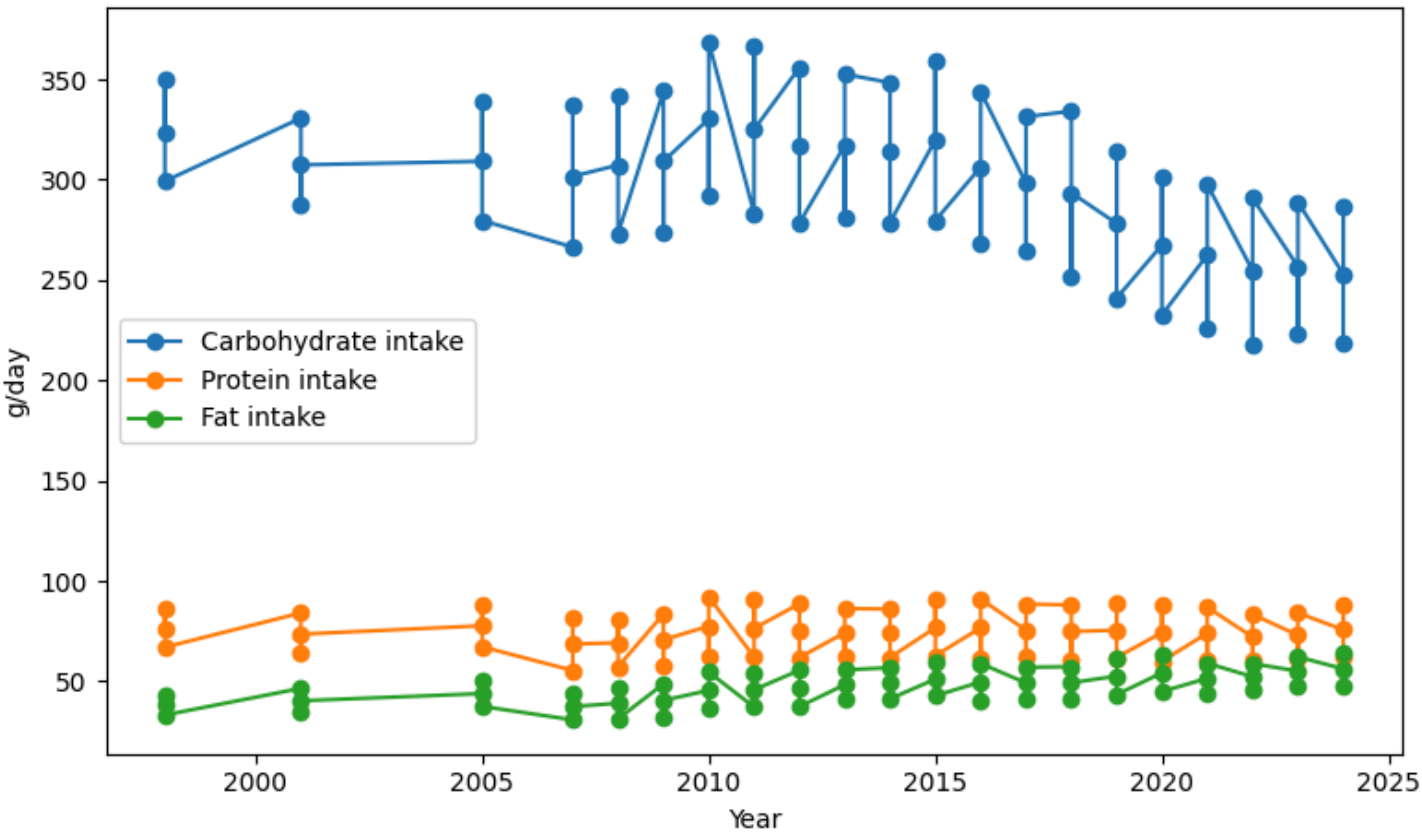


Figure 1

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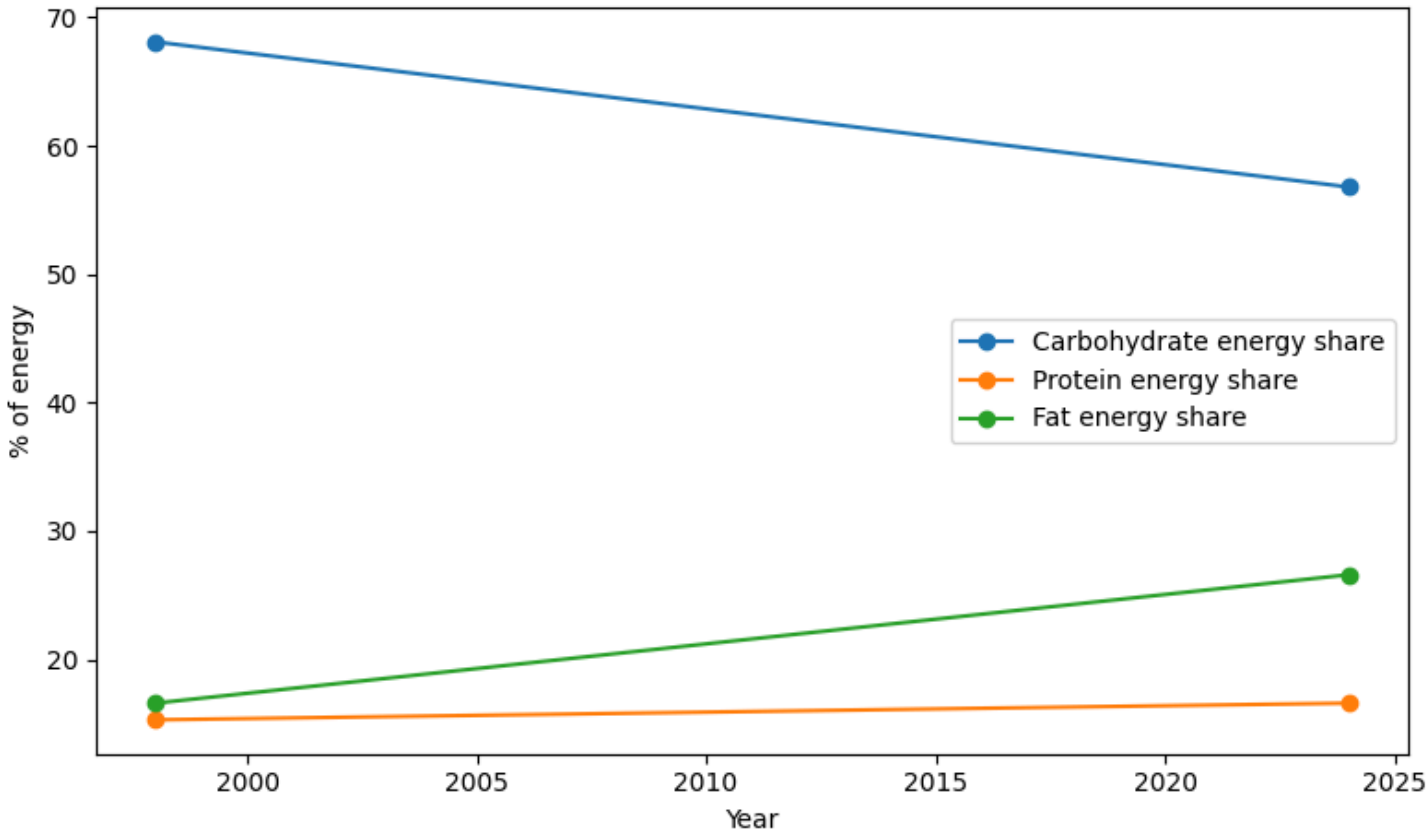


Figure 2

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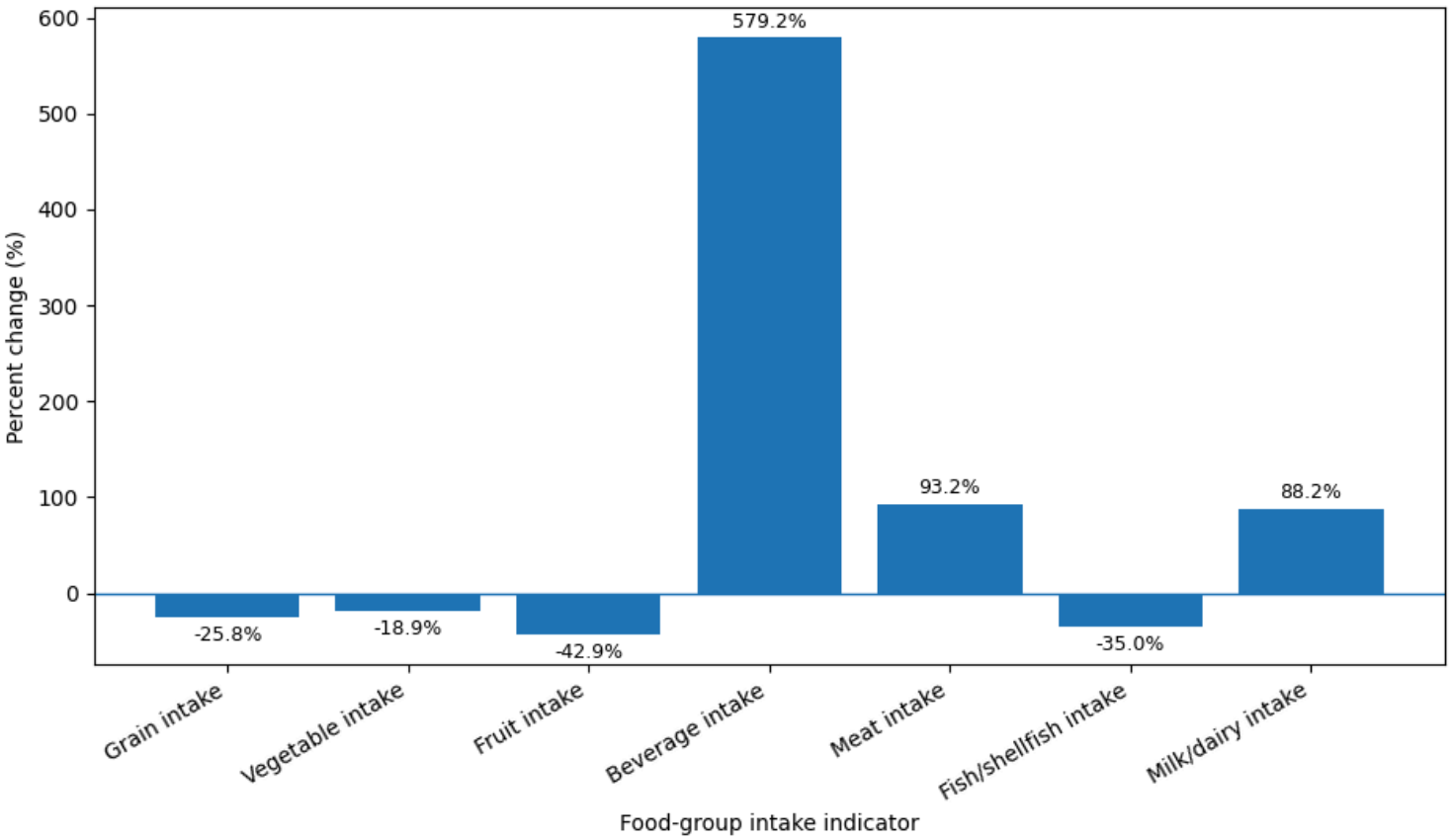


Figure 3

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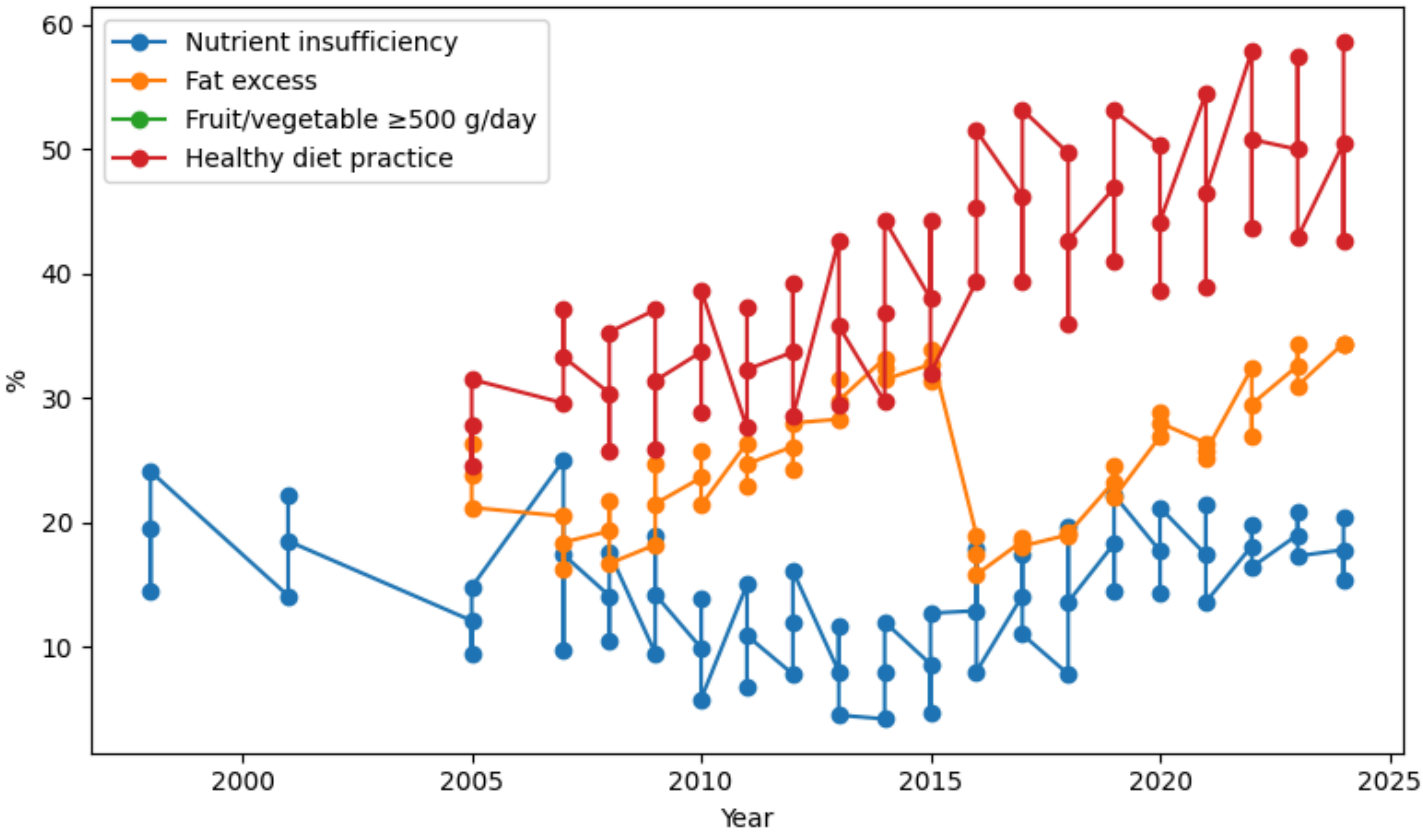


Figure 4

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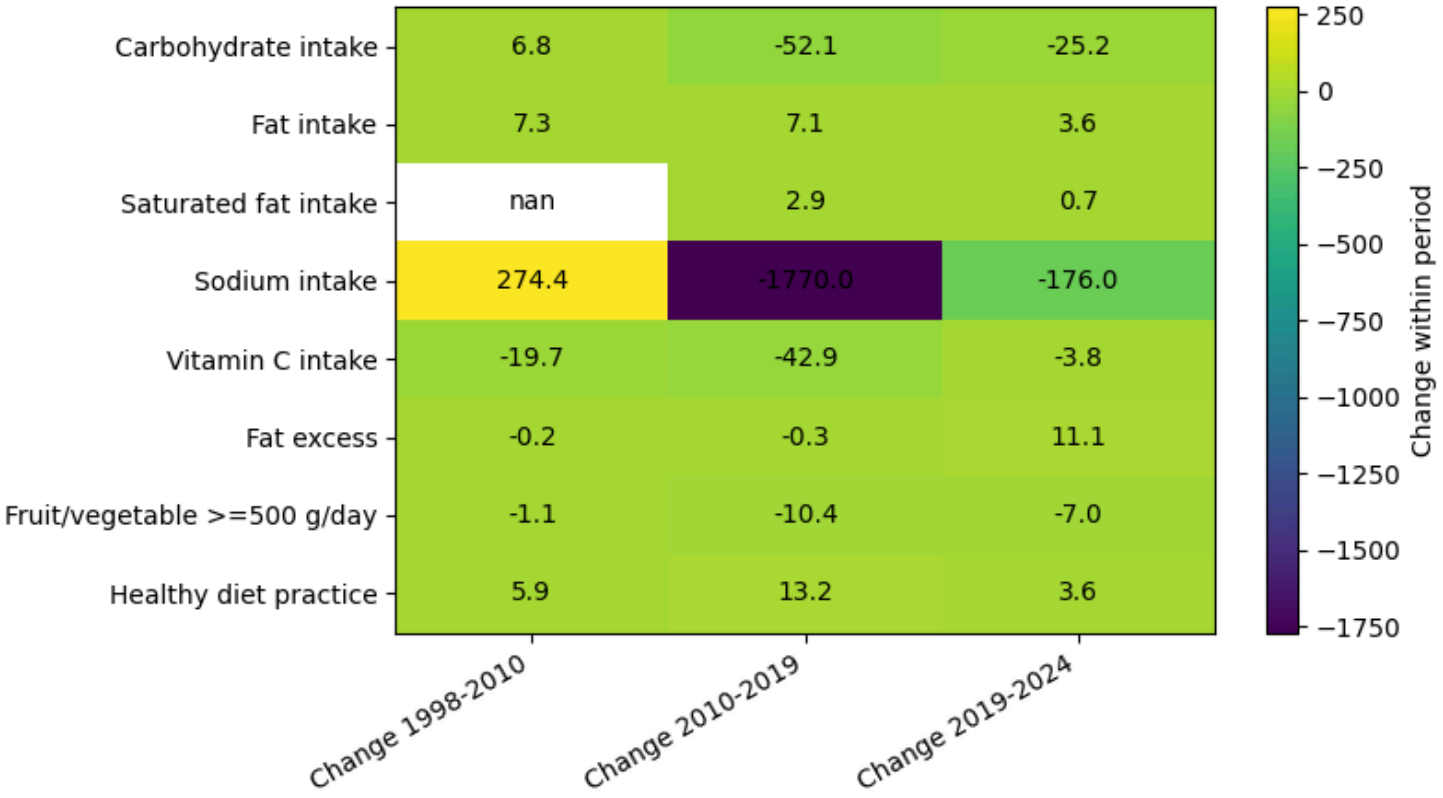


Figure 5

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