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# Adherence to Dietary Patterns and Cardiovascular Disease Risk: A Cross-Sectional Study of Total Carotid Plaque Area in Argentina

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## ABSTRACT

**Objective:** Assessing subclinical atherosclerosis (sAT) is crucial for preventing cardiovascular disease. The Mediterranean diet is considered the gold standard for cardiovascular protection, but cultural and economic barriers can hinder adherence to it. The prudent dietary pattern (DP) has been associated with protective effects against chronic diseases. However, its impact on primary cardiovascular prevention remains uncertain. This study examined adherence to various DPs and their effect on sAT, measured by total carotid plaque area (TPA).
**Methods:** This cross-sectional study included 116 adults enrolled in a cardiovascular prevention program. Demographic, clinical, laboratory, and TPA data were collected. Adherence to DPs was assessed using a food frequency questionnaire. Participants were categorized according to their adherence to 4 mutually exclusive DPs: prudent, traditional, sweet, and mixed. Generalized linear models were used to assess the effect of DPs on TPA, adjusting for relevant cardiovascular variables.
**Results:** The traditional, sweet, and mixed DPs were associated with higher TPA values than the prudent DP, with medians (interquartile range) of 27 (99), 39 (49), 27.5 (58), and 0 (36) $mm^2$, respectively. Gamma regression analysis found that the beta exponents for the traditional, sweet, and mixed DPs versus the prudent DP were 3.78 ($p$=0.046); 3.73 ($p$=0.013), and 2.20 ($p$=0.072), respectively. Systolic blood pressure values were higher for the sweet and mixed DPs than for the prudent DP (133.9±11.7; 132.5±13.9 and 122.7±8.8 mmHg, respectively; $p$<0.05).
**Conclusion:** These findings underscore the importance of additional research and targeted interventions to promote healthier DPs to promote improvements in cardiovascular health.

**Keywords:** Dietary patterns; Carotid atherosclerosis; Cardiovascular disease

## INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of death worldwide.[1] These diseases are preceded by a long asymptomatic latent period, offering a valuable opportunity for early

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**Conflict of Interest**
The authors have no conflicts of interest to declare.

**Data Availability Statement**
The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request. Data files are also available from Harvard Dataverse: https://doi.org/10.7910/DVN/SL5J9N.

**Author Contributions**
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cardiovascular prevention interventions.[2] Atherosclerosis (AT) is the main cause of cardiovascular events,[3] and assessing subclinical AT (sAT) is an effective tool for their prevention.[4]

Diets significantly influence cardiovascular health, either positively or negatively.[5] Many studies have focused on the impact of specific food groups,[6-9] but this study design does not permit an analysis of the diet as a whole or the synergistic effects of different foods.[10] Consequently, recent dietary research has shifted towards studying dietary patterns (DPs), which represent the totality of foods and beverages consumed,[11,12] and evaluating the interactions among dietary components and their effects on AT.[10]

Adherence to the Mediterranean diet has been shown to reduce the intima-media thickness (IMT),[13,14] coronary artery calcification (CAC),[15] and the incidence of cardiovascular events.[16] However, this diet is only sometimes followed in Argentina. Thus, it is necessary to analyze the potential cardiovascular benefits of the DPs already present in this region. To our knowledge, no studies have yet investigated the effects of DPs on CVD in Argentina. A study conducted in Córdoba, Argentina, found that the prudent DP, which was commonly consumed by the study population, was linked to a lower risk of breast and colorectal cancer.[17] Subsequent research examined DPs and the components of metabolic syndrome.[18] However, there is still no evidence regarding whether the prudent DP confers benefits for primary cardiovascular prevention.

Most studies have analyzed DPs in relation to AT based on only cardiovascular risk factors. However, as Spence[19] (2020) pointed out, studying AT by examining the arteries themselves is crucial. Assessing AT is a useful method to prevent CVD, as the total carotid plaque area (TPA) is a strong indicator of cardiovascular risk and can be modified by treatment.[20]

In Argentina, where CVD is the leading cause of mortality, the Mediterranean diet has been extensively studied, but it is not commonly followed in our population. Local studies on the impact of common dietary habits on the TPA-assessed AT burden are lacking. Therefore, this study aims to make a modest contribution to the intricate puzzle of AT by analyzing adherence to the DPs prevalent in our population and their modulation of TPA as a marker of sAT.

## MATERIALS AND METHODS

### 1. Selection of study participants

A cross-sectional observational study was conducted on individuals aged 35 to 75 of both sexes who participated in a cardiovascular prevention program between 2019 and 2022.

Patients who met all inclusion criteria and had no exclusion criteria were included. The inclusion criteria were: written informed consent, age between 35 and 75 years, intermediate cardiovascular risk based on the Framingham Heart Study-CVD (10-year risk) using body mass index (BMI),[21] and complete laboratory analysis (lipid and glycemic profile, renal function, thyroid function) within ±3 months of the TPA study in a central laboratory. The exclusion criteria were as follows: a previous cardiovascular event, pathology, or surgical condition affecting the intestinal absorption of food intake, rheumatic disease, autoimmune disease, respiratory failure, renal failure, liver disease, thyroid stimulating hormone and/or thyroid hormone T4 outside the normal range, glycosylated hemoglobin greater than 7%, moderate/severe cognitive impairment, dementia, moderate/severe depression/anxiety, or any condition that, in the investigator's opinion, would jeopardize the ability to adhere to the protocol. Additionally, individuals with laboratory studies conducted within ±3 months of the TPA study but >3 months of the food questionnaire were excluded.

Out of a total of 3,000 participants in the program, 1,680 had not undergone a TPA study or laboratory analysis of their lipid and glycemic profiles within ±3 months of the TPA. Thus, the inclusion criteria were evaluated in the remaining 1,320 individuals. Among these, 1,178 did not meet the inclusion criteria, and 19 did not agree to participate. Hence, 123 individuals without any exclusion criteria consented to participate (RePIS No. 3884).

### 2. Data collection

Information on personal history of hypertension, diabetes, smoking, medication consumption, family history of cardiovascular events, carotid TPA measured by high-resolution duplex ultrasound in the carotid artery,[22] blood pressure measured on the same day of TPA assessment, and laboratory data including total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, triglycerides, blood glucose, and glycosylated hemoglobin, were obtained from clinical records. Smoking was considered present if the individual currently smoked or had smoked in the past.

### 3. Dietary assessment

A dietary interview was conducted using a validated semiquantitative food frequency questionnaire (127 items).[23] The instrument inquired about the frequency of daily, weekly, and monthly intakes, as well as the number and size of the portions. A photographic atlas was used as visual support to identify portion sizes (small/medium/large). Subsequently, each individual's daily food or beverage intake and nutrient intake were calculated in grams or cubic centimeters based on the information collected in the food frequency questionnaire, using the Nutrio V2 software.[24]

### 4. DP adherence analysis

Based on the DPs described by the Group of Environmental Epidemiology of Cancer and Other Chronic Diseases in a population-based study,[18] which were constructed from principal component factor analysis, using varimax rotation to facilitate their interpretation, the food groups included in the analysis were formed according to the nutritional properties of the foods. A factor loading was considered high if it was |≥0.45|. The Kaiser-Meyer-Olkin measure was 0.71, indicating an acceptable/good value. The number of factors retained was determined using the Kaiser-Guttman criterion, which suggests retaining as many factors as there are sample eigenvalues greater than 1.[25,26]

The DPs identified in the factor analysis were as follows: traditional: high factor loadings of eggs/meats (except fish), processed meats, starchy vegetables/refined grains, sweet foods and oils; prudent: high factor loadings of non-starchy vegetables, fruits, whole grains, legumes and nuts/seeds; and sweet: high factor loadings of sweet foods and non-alcoholic beverages.

Based on the score of each factor, we evaluated the tertiles of adherence (low/moderate/high) of our study participants to the described DPs. Since individuals can adhere to more than one DP, participants in our study were grouped into four categories: prudent DP (those who adhered only to the prudent DP), traditional DP (those who adhered only to the traditional DP), sweet DP (those who adhered only to the sweet DP), and mixed (those who adhered to both the prudent DP and either the traditional or sweet DP). Individuals with low adherence


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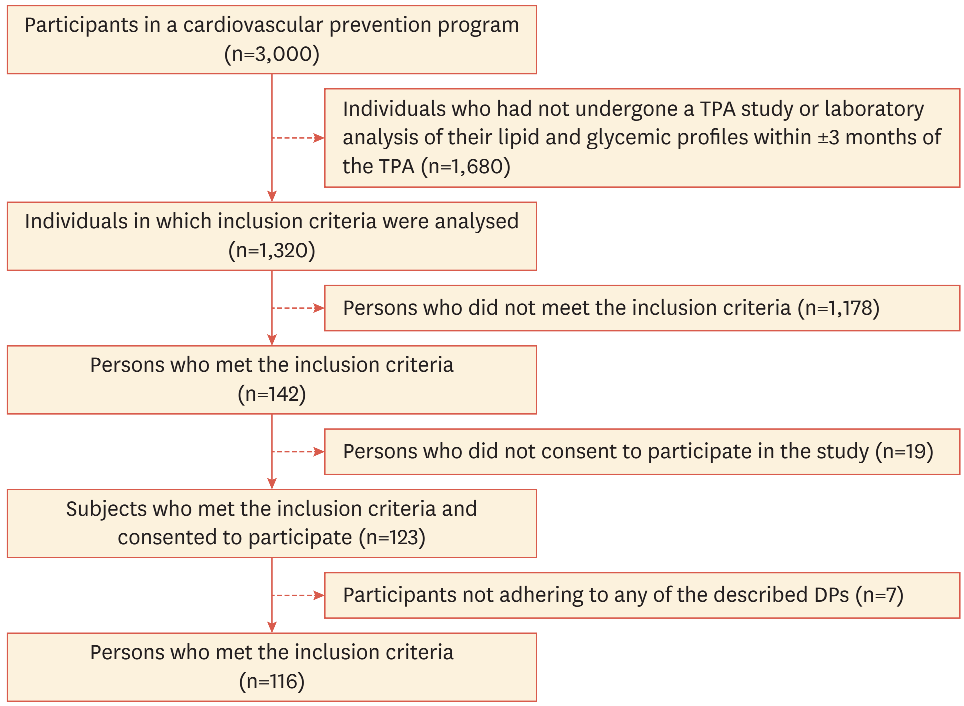


**Fig. 1.** Flow chart of participants included.
TPA, total carotid plaque area; DP, dietary pattern.

to all these DPs were excluded from this analysis (n=7), resulting in a total of 116 participants in the study (**Fig. 1**).

### 5. Statistical analysis

The descriptive analysis was conducted using the Shapiro-Wilks normality test for each variable. Variables that followed a normal distribution were summarized as mean±standard deviation and analyzed using *t*-tests and analysis of variance. For variables with a skewed distribution, the median (interquartile range) and Kruskal-Wallis tests were employed.

To examine the relationship between TPA load ($mm^2$) and DPs, as well as classical cardiovascular risk factors, we employed generalized linear models with a gamma distribution and a log link function.[27] The results were reported as exponentiated coefficients, expressed as the beta exponent. We conducted three models: 1) one including only DPs in the linear predictor; 2) another adding age in tertiles and sex; and 3) a third incorporating total caloric intake, BMI, systolic blood pressure (SBP), high-density lipoprotein cholesterol, triglycerides, and smoking habits. The reference DP used in the models was the prudent DP. All statistical analyses were performed using Stata 17.0 (StataCorp).[28]

## RESULTS

A total of 116 adults, with a mean age of 59±11 years and a mean BMI of 30.1±4.7 $kg/m^2$, participated in the study. The general characteristics, personal clinical history, lipid and glycemic profile values, BMI, and blood pressure measurements, both overall and stratified by DP, are presented in **Table 1**. A significant difference in SBP was observed between the

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sweet and mixed DPs compared to the prudent DP, with values of 133.9±11.7, 132.5±13.9, and 122.7±8.8 mmHg, respectively ($p<0.05$). A similar pattern was noted for diastolic blood pressure, with values of 78.6±8.4, 78.2±8.8, and 72.9±10.3 mmHg, respectively ($p<0.05$). No significant differences were found in the other variables between the DPs. The consumption of various food groups, expressed in grams or cc/day according to adherence to the DP, is shown in **Table 2**.

**Fig. 2** visually illustrates the differences in TPA, presenting a detailed percentile distribution. The traditional, sweet, and mixed DPs showed higher median (interquartile range) TPAs

**Table 1.** Characteristics of the study population based on their adherence to dietary patterns

| Variables | Total (n=116) | Prudent (n=20) | Traditional (n=13) | Sweet (n=22) | Mixed (n=61) | *p*-value |
|---|---|---|---|---|---|---|
| Age (yr) | 59±11 | 56±13 | 56±13 | 62±10 | 60±11 | 0.255 |
| Sex | | | | | | 0.478 |
| Male | 36.2 | 30.0 | 38.5 | 50.0 | 32.8 | |
| Female | 63.7 | 70.0 | 61.5 | 50.0 | 67.2 | |
| Hypertension | 60.3 | 55.0 | 84.6 | 77.3 | 68.8 | 0.257 |
| Diabetes | 27.6 | 35.0 | 30.8 | 36.4 | 21.3 | 0.446 |
| FH-CVe | 20.0 | 31.6 | 27.3 | 9.5 | 18.6 | 0.325 |
| Smoking | 50.9 | 55.0 | 38.5 | 54.5 | 50.8 | 0.788 |
| BMI (kg/m$^2$) | 30.1±4.7 | 29.6±5.8 | 30.5±4.9 | 29.9±4.5 | 30.2±4.5 | 0.948 |
| SBP (mmHg) | 130.4±13.8 | 122.7±8.8 | 125.8±18.3 | 133.9±11.7* | 132.5±13.9* | 0.016 |
| DBP (mmHg) | 77.3±9.8 | 72.9±10.3 | 77.4±13.8 | 78.6±8.4† | 78.2±8.8* | 0.197 |
| Total cholesterol (mg/dL) | 181.5±41.7 | 171.0±46.9 | 188.0±51.2 | 179.7±40.7 | 184.4±38.5 | 0.618 |
| LDL cholesterol (mg/dL) | 103.2±36.1 | 91.6±38.8 | 106.9±42.9 | 103.3±34.9 | 106.2±34.3 | 0.489 |
| HDL cholesterol (mg/dL) | 50.5±13.6 | 52.3±13.3 | 48.5±15.3 | 51.4±19.0 | 50.0±10.8 | 0.868 |
| Triglycerides (mg/dL) | 127.0 (81) | 133.0 (85) | 130.0 (83) | 138.0 (71) | 123.0 (74) | 0.881 |
| Blood glucose level (mg/dL) | 100.0 (17) | 98.5 (29) | 98.0 (15) | 101.0 (25.5) | 99.0 (16) | 0.929 |
| Hypercholesterolemia medication | 51.7 | 60.0 | 53.85 | 72.73 | 40.98 | 0.064 |
| Hypoglycemia medication | 20.7 | 35.00 | 15.38 | 18.18 | 18.03 | 0.382 |
| Insulin | 4.3 | 5.00 | 7.69 | 4.55 | 3.28 | 0.909 |
| Anticoagulant medication | 25.0 | 35.00 | 30.77 | 18.18 | 22.95 | 0.577 |
| Antihypertensive medication | 56.9 | 50.00 | 61.54 | 54.55 | 59.02 | 0.882 |

Values are presented as mean ± standard deviation or median (interquartile range) or number (%).
The *p*-values for categorical variables were calculated using the chi-square test, while those for numerical variables were calculated using analysis of variance.
FH-CVe, family history of cardiovascular event; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; LDL, low-density lipoprotein; HDL, high-density lipoprotein.
*$p<0.05$ compared to the prudent DP with the *t*-test for parametric variables and the Kruskall-Wallis test for non-parametric variables.
†$p=0.06$ compared to the prudent DP with the *t*-test for parametric variables and the Kruskall-Wallis test for non-parametric variables.

**Table 2.** Food group consumption according to adherence to DP

| Food groups | Prudent DP | Traditional DP | Sweet DP | Mixed DP | Total |
|---|---|---|---|---|---|
| Dairy | 246 (355) | 140 (139) | 214 (314) | 194 (369) | 195 (339) |
| Whole grain cereal | 12 (84) | 0 (0) | 0 (35) | 13 (70) | 2 (60) |
| Non-starchy vegetables | 516 (284) | 350 (269) | 205 (129) | 387 (301) | 359 (312) |
| Starchy vegetables | 7 (26) | 107 (50) | 35 (71) | 24 (74) | 26 (84) |
| Refined grain | 65 (111) | 295 (204) | 143 (129) | 128 (172) | 129 (173) |
| Fruits | 228 (195) | 152 (189) | 198 (214) | 257 (294) | 228 (255) |
| Nuts/seeds | 4 (15) | 0 (0) | 0 (1) | 1 (6) | 1 (6) |
| Legumes | 7 (11) | 0 (0) | 0 (1) | 2 (7) | 1 (7) |
| Meat and eggs (except fish) | 209 (180) | 492 (218) | 196 (147) | 220 (234) | 237 (223) |
| Fish | 10 (19) | 0 (8) | 0 (5) | 9 (24) | 5 (16) |
| Processed meats | 1 (24) | 54 (17) | 15 (26) | 10 (35) | 15 (36) |
| Sweet foods | 2 (10) | 33 (132) | 28 (56) | 9 (23) | 11 (32) |
| Oils | 19 (6) | 37 (32) | 19 (14) | 20 (30) | 20 (15) |
| Non-alcoholic beverages | 0 (14) | 400 (500) | 282 (750) | 107 (400) | 100 (400) |
| Alcoholic beverages | 0 (0) | 58 (143) | 0 (0) | 0 (0) | 0 (13) |

Values are presented as median (interquartile range). Values expressed in g/day.
DP, dietary pattern.

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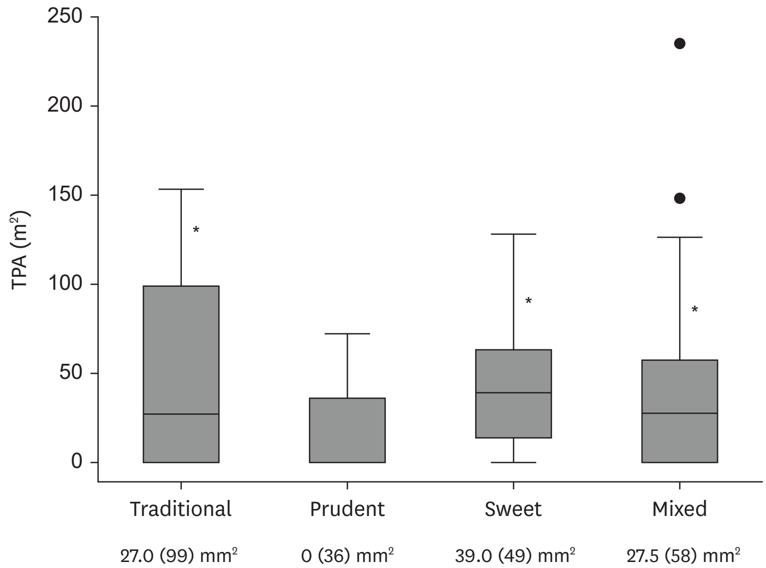


**Fig. 2.** Box plot between DPs and carotid total plaque area, expressed in mm$^2$. Values expressed as median (interquartile range). In the graphic, the line inside the box expresses the median TPA load for each DP. The bottom of the box is the 25th percentile, and the top is the 75th percentile. Note that in the prudent DP box, the line corresponding to the median value coincides with the lower one, being 0 mm$^2$.
TPA, total carotid plaque area; DP, dietary pattern.
*$p$<0.05 vs. the prudent DP. There were no significant differences between the traditional, sweet, and mixed DPs.

compared to the prudent DP, with respective TPA values of 27.0 (99) mm$^2$, 39.0 (49) mm$^2$, 27.5 (58) mm$^2$, and 0.0 (36) mm$^2$.

**Table 3** shows that in models 1 and 2, individuals adhering to the traditional, sweet, and mixed DPs had a higher TPA load than those following the prudent DP. In model 3, the TPA load was also higher in individuals on the traditional and sweet DPs, and to a lesser extent, the mixed DP, when compared to the prudent DP (beta exponent=3.78, $p$=0.046; beta exponent=3.73, $p$=0.013; and beta exponent=2.20, $p$=0.072).

**Table 3.** Carotid total plaque area according to DPs and classic risk factors

| Variables | Beta exponent* | Standard errors | $p$-value | 95% CI |
|---|---|---|---|---|
| Traditional DP | | | | |
| Model 1 | 2.55 | 1.08 | 0.028 | 1.10–5.87 |
| Model 2 | 2.73 | 1.35 | 0.041 | 1.04–7.17 |
| Model 3 | 3.78 | 2.53 | 0.046 | 1.02–14.0 |
| Sweet DP | | | | |
| Model 1 | 2.49 | 0.92 | 0.013 | 1.20–5.14 |
| Model 2 | 2.88 | 1.24 | 0.014 | 1.24–6.69 |
| Model 3 | 3.73 | 1.99 | 0.013 | 1.31–10.59 |
| Mixed DP | | | | |
| Model 1 | 2.29 | 0.71 | 0.007 | 1.25–4.19 |
| Model 2 | 2.28 | 0.84 | 0.024 | 1.11–4.69 |
| Model 3 | 2.20 | 0.97 | 0.072 | 0.93–5.21 |

Response variable: total carotid plaque area (continuous).
DP, dietary pattern; CI, confidence interval; Model 1, unadjusted; Model 2, adjusted for age (tertile) and sex; Model 3, adjusted for model 2, as well as the total caloric value, body mass index, systolic blood pressure, high-density lipoprotein cholesterol, triglycerides, and smoking status.
*Reference value: prudent DP.


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## DISCUSSION

In the present study, we examined the association between TPA and adherence to DPs previously identified in Argentina, namely traditional, sweet, and prudent. It is important to note that an individual can adhere to more than one DP; therefore, each DP should not be considered as an independent set. Accordingly, three DPs were constructed based on exclusive and non-overlapping adherence to the mentioned patterns (only traditional, only sweet, only prudent), and a fourth pattern, called mixed, was created for those who adhered to both prudent and traditional and/or sweet. Adhering to the sweet, traditional, or even mixed DPs was associated with a higher likelihood of having more atherosclerotic plaque, as measured by TPA, compared to adhering to the prudent DP across all models examined. This indicates that consuming a prudent DP alone is not a sufficient condition for the prevention of CVD if adherence to traditional and/or sweet DPs is also maintained.

Few studies have analyzed atherosclerotic plaque burden specifically in relation to DP. In these studies, the primary methods for measuring atherosclerotic plaque burden have included IMT,[13,29,30] presence of plaque,[30] and CAC,[29,31,32] and, to a lesser extent, TPA.[33] The latter is a strong predictor of cardiovascular events and is responsive to therapy.[34-36] Furthermore, when comparing TPA with other methods of plaque burden determination, Mathiesen et al.[37] (2011) observed that TPA appeared to be a stronger predictor of first stroke than IMT. Moreover, TPA shows a strong correlation with CAC scores as a risk predictor, while offering advantages such as lower cost, no radiation exposure, and the ability to detect non-calcified plaque.[19,38]

Pignanelli et al.[33] (2018) explored the relationship between adherence to the Mediterranean diet and TPA, with a secondary focus on individuals in the upper quartile of TPA. Although the Mediterranean diet and the prudent DP do not completely overlap, both include a substantial amount of non-starchy vegetables and fruits. However, Pignanelli's study did not find a significant association between levels of adherence to the Mediterranean diet and TPA,[33] probably because, unlike our study, it was conducted in individuals with high cardiovascular risk.

Despite differences among the various methods for determining AT, Liu et al.[30] (2021) in a study conducted in China, observed three DPs through factor analysis, including a sweets pattern. Women in the highest quartile of this pattern had higher IMT than those in the lowest quartile (odds ratio [OR], 1.64; 95% confidence interval [CI], 1.08–2.51). Additionally, Gorgulho et al.[32] (2021), found that the convenient DP, which shares some food items with the traditional DP in our study, increased the chances of having a CAC score >100 by 33% (OR, 1.33; 95% CI,1.02–1.74; $p$=0.036) compared to individuals with CAC score of 0. However, other patterns such as prudent, healthy and plant-based, and dairy and plant-based DPs did not show a relationship with AT. These studies used different ways to find AT and examined different levels of adherence without taking into account the effect of consuming multiple DPs. This could explain why the impacts of the prudent DP on AT were not consistent.

Other studies have analyzed the relationships between AT and particular food groups.[6-9] Although these studies have provided abundant information that has contributed to advancing knowledge in the field, they fall short of providing a comprehensive analysis of DPs. In this context, the 2020–2025 Dietary Guidelines for Americans[12] emphasize the importance of considering overall healthy eating patterns, taking into account the cultural preferences of the population. In our research, although there are differences compared to previous studies, we found that the prudent DP played a role in preventing AT. This DP is characterized by a high factorial load of non-starchy vegetables, fruits, whole grains, legumes, and nuts/seeds, all of which are rich in nutrients that possess anti-inflammatory and antioxidant properties, aiding in the prevention of chronic diseases.[39] Conversely, the traditional and sweet DPs are associated with a high factorial load of eggs/meats (excluding fish), processed meats, starchy vegetables/refined grains, oils, sugary foods, and sugary beverages, respectively. These items, typically including cold cuts, cookies, candies, and sodas, are high in simple sugars, saturated fats, sodium, and other harmful components. Both the Dietary Guidelines for the Argentine population[40] and the 2020–2025 Dietary Guidelines for Americans recommend reducing the intake of these foods due to their negative health impacts.[12]

One limitation of the present study is the exclusion of chronic diseases or clinical conditions known to interfere with the AT process, which was necessary to minimize confounding factors in TPA. This exclusion resulted in a smaller sample size. However, this approach also strengthens the study by controlling intervening factors in TPA through the use of strict inclusion/exclusion criteria. Therefore, future studies should be conducted with a larger sample and less restrictive exclusion criteria to analyze a more representative clinical population, with subsequent adjustments in the analysis models. The assessment of food intake was based on a validated food frequency questionnaire, which captured the habitual consumption of foods over the past year. The administration of this questionnaire by a trained and qualified professional minimized participant recall bias. The strength of this article lies in its novel approach to analyzing DPs in relation to AT, which, to our knowledge, has not been previously reported in the literature. Additionally, it facilitates the study of AT in relation to DPs specific to our population, enabling the generation of recommendations that align with local dietary habits.

Therefore, considering the results of this study, it is crucial to further investigate the relationship between DPs and AT, given that healthy eating significantly contributes to the prevention of cardiovascular events.[41] Understanding this association can help in developing tailored dietary recommendations that align with the eating habits of specific populations.

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