ΓΕΩΠΟΝΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

ΤΜΗΜΑ ΕΠΙΣΤΗΜΗΣ ΤΡΟΦΙΜΩΝ ΚΑΙ ΔΙΑΤΡΟΦΗΣ ΤΟΥ ΑΝΘΡΩΠΟΥ

ΕΡΓΑΣΤΗΡΙΟ ΧΗΜΕΙΑΣ ΚΑΙ ΑΝΑΛΥΣΗΣ ΤΡΟΦΙΜΩΝ

Διδακτορική Διατριβή

Διερεύνηση των διατροφικών προτύπων σε ένα εθνικά αντιπροσωπευτικό δείγμα ενηλίκων στην Ελλάδα και η σχέση τους με παράγοντες τρόπου ζωής και τα καρδιαγγειακά νοσήματα: στοιχεία από την Πανελλαδική Μελέτη Διατροφής και Υγείας.

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Επιβλέπων καθηγητής: Αντώνης Ζαμπέλας

Αθήνα, Σεπτέμβριος 2018

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Σεπτέμβριος 2018

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PhD Thesis

«Empirically-derived dietary patterns and their association with lifestyle factors and cardiovascular disease in a representative sample of the Greek adult population: the Hellenic National Nutrition and Health Survey.»

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«The food you eat can be the safest form of medicine
or the slowest form of poison»

Ann Wigmore

Ευχαριστίες

Θα ήθελα να ευχαριστήσω θερμά τον κύριο Αντώνη Ζαμπέλα για τη συνεργασία, την εμπιστοσύνη, την υποστήριξη και τη βοήθεια καθόλη τη διάρκεια εκπόνησης της μελέτης και, κυρίως, για την ευκαιρία που μου έδωσε να είμαι μέλος μίας ομάδας που έστησε μία σπουδαία για τα ελληνικά δεδομένα εθνική μελέτη.

Θα ήθελα, επίσης, να ευχαριστήσω την κα. Εμμανουέλα Μαγρίπλη για την καθοδήγηση και την πολύτιμη βοήθεια στο στατιστικό μέρος της μελέτης, καθώς και τον κ. Δημοσθένη Παναγιωτάκο για τις συμβουλές και τα καίρια σχόλια κατά τη συγγραφή των άρθρων της μελέτης. Ένα μεγάλο ευχαριστώ σε όλη την ομάδα της ΠΑ.ΜΕ.Δ.Υ. και στον καθένα ξεχωριστά που δουλέψαμε για σχεδόν 3 χρόνια μαζί και μοιραστήκαμε αγωνίες, άγχη και προθεσμίες χωρίς να χάνουμε την καλή μας διάθεση... για πολύ.

Ιδιαίτερο ευχαριστώ στην Δρ. Ιωάννα Μπακογιάννη, τη συνοδοιπόρο μου σε όλη αυτή την εμπειρία, για την ανεκτίμητη συμπαράσταση και στήριξη (ηθική, ψυχολογική και πρακτική). Τέλος, θα ήθελα να ευχαριστήσω από καρδιάς τους γονείς μου -χωρίς την στήριξή τους δεν θα ήμουν εδώ- την αδερφή μου και όλους τους ήρωες-φίλους μου που είναι πάντα εκεί για εμένα να με ακούν, να με ανέχονται και να με πιστεύουν και φυσικά τον σύντροφο μου για όλα τα παραπάνω και επειδή είναι το χαμόγελο στη μέρα μου.

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Abstract

Background: Dietary pattern assessment is now the focus of nutritional epidemiology. Dietary patterns have been related to multiple health outcomes, during the past decades, mainly CVD. Empirically-derived dietary patterns have been shown to have both positive and adverse associations with cardiovascular disease (CVD). Yet, the association of distinct dietary patterns with CVD remains unclear in the Greek population.

Aims: To identify the underlying dietary patterns in a representative sample of adults in Greece, and investigate the associations between empirically-derived dietary patterns and (a) demographic characteristics and lifestyle factors, and (b) cardiovascular disease and risk factors.

Methods: This was a cross-sectional study. Adult participants (≥20 years old) of the Hellenic National Nutrition and Health Survey (HNNHS) were included (N=3,552; 41.2% men; 43.7 years, SD: 18.1). Dietary patterns were derived by principal component analysis using 24-hour recall data. Analysis of variance and chi-square test were used to determine the demographic and lifestyle characteristics of the patterns. The presence of CVD and CVD-related medical conditions, including dyslipidemia (i.e., elevated cholesterol and/or triglycerides) and hypertension, was self-reported and defined according to the International Clinical Diagnosis (ICD)-10 codes. Odds ratios of CVD outcomes were estimated across dietary patterns using multivariable logistic regression analysis.

Results: Three dietary patterns were identified explaining 16.5% of variance; a Traditional pattern, loading positively on olive oil, non-starchy vegetables, and cheese; a Western pattern, loading positively on refined grains, processed meats, and animal fats; and a Prudent pattern, loading positively on fruit, whole grains, and yoghurt, and negatively on fast-food. A fourth, Snack-type pattern, loading positively on sweets, salty snacks and nuts, was identified in women. Primary crude results revealed an association between dietary patterns and socioeconomic status. In multivariate analysis, highest adherence to the Prudent pattern was associated with higher protein and unsaturated fat intake, and lower energy and saturated fat intake (all $P \leq 0.05$); the Western and Traditional patterns were associated with higher energy, and total and saturated fat intake; the

Traditional pattern was additionally associated with higher monounsaturated fatty acids intake, whereas the Western pattern with higher alcohol intake (all $P \leq 0.001$). Logistic regression analysis, adjusted for age and sex, showed an inverse association between the Traditional dietary pattern and total CVD (OR: 0.53; 95% CI: 0.31-0.92), and a positive association between the Western pattern and dyslipidemia (1.49; 1.08-2.05); further adjustments did not change these associations (0.53; 0.29-0.97 and 1.52; 1.02-2.26). The Prudent pattern was not significantly associated with total CVD outcome nor with dyslipidemia.

Conclusions: There are significant associations between empirically-derived dietary patterns and CVD prevalence among the Greek adult population. These findings are valuable for understanding the dietary behaviors of adults in Greece and enabling more focused public health policies for the promotion of healthier food behaviors.

Field of science: Health Sciences

Key words: diet; dietary patterns; diet intake; cardiovascular disease; lifestyle; nationally representative survey; principal component analysis

Περίληψη

Εισαγωγή: Η διερεύνηση και αξιολόγηση των διατροφικών προτύπων αποτελεί πλέον το επίκεντρο της επιδημιολογίας της διατροφής. Τα τελευταία χρόνια, τα διατροφικά πρότυπα έχουν συσχετιστεί με πολλαπλούς δείκτες υγείας και νοσήματα και κυρίως με τα καρδιαγγειακά νοσήματα. Συγκεκριμένα, τα διατροφικά πρότυπα που προκύπτουν από την εκ των υστέρων (*a posteriori*) μέθοδο έχουν συσχετιστεί τόσο θετικά όσο και αρνητικά με τα καρδιαγγειακά νοσήματα. Η αξιολόγηση της σχέσης των διατροφικών προτύπων με τα καρδιαγγειακά νοσήματα στον ελληνικό πληθυσμό παραμένει ασαφής.

Σκοπός: Η διερεύνηση των υποκείμενων διατροφικών προτύπων σε ένα εθνικά αντιπροσωπευτικό δείγμα ενηλίκων στην Ελλάδα και η αξιολόγηση της σχέσης τους με δημογραφικά χαρακτηριστικά, παράγοντες τρόπου ζωής, καρδιαγγειακά νοσήματα και παράγοντες κινδύνου.

Μεθοδολογία: Η έρευνα στην οποία βασίστηκε η ανάλυση είναι η Πανελλαδική Μελέτη Διατροφής και Υγείας (ΠΑ.ΜΕ.Δ.Υ.), μία συγχρονική μελέτη με εθνικά αντιπροσωπευτικό δείγμα ανεξαρτήτου φύλου και ηλικιακής ομάδας. Στην ανάλυση συμπεριλήφθησαν μόνο οι ενήλικοι (≥20 ετών) συμμετέχοντες της μελέτης (N=3,552, 41.2% άνδρες; 43.7 ετών, SD: 18.1). Για την ανίχνευση και τον προσδιορισμό των διατροφικών προτύπων εφαρμόστηκε η ανάλυση κυρίων συνιστωσών (Principal Component Analysis, PCA), χρησιμοποιώντας διατροφικά δεδομένα που είχαν συλλεχθεί μέσω 24ώρης ανάκλησης. Ο χαρακτηρισμός των διατροφικών προτύπων βάσει δημογραφικών χαρακτηριστικών και τρόπου ζωής των συμμετεχόντων πραγματοποιήθηκε με ανάλυση διακύμανσης (Analysis of Variance, ANOVA) και τον έλεγχο ανεξαρτησίας χ^2. Η παρουσία καρδιαγγειακών νοσημάτων και παραγόντων κινδύνου, όπως η δυσλιπιδαιμία (υψηλά επίπεδα χοληστερόλης ή/και τριγλυκεριδίων) και η υπέρταση, δηλώθηκε από τους ίδιους τους συμμετέχοντες, ενώ η κατηγοριοποίηση έγινε βάσει της Διεθνούς Στατιστικής Ταξινόμησης Νόσων και Συναφών Προβλημάτων Υγείας (Δέκατη Αναθεώρηση) του Παγκόσμιου Οργανισμού Υγείας. Ο λόγος σχετικών πιθανοτήτων (odds ratio) για τα καρδιαγγειακά νοσήματα ανά διατροφικό πρότυπο

υπολογιστήκε με τη μέθοδο της πολλαπλής λογιστικής παλινδρόμησης (multivariable logistic regression analysis).

Αποτελέσματα: Τρία κύρια διατροφικά πρότυπα ανιχνεύθηκαν στον πληθυσμό της μελέτης, τα οποία εξηγούσαν το 16.5% της διακύμανσης: ένα Παραδοσιακό, ένα Δυτικού τύπου και ένα Συνετό πρότυπο. Το Παραδοσιακό πρότυπο είχε σημαντική θετική συσχέτιση με το ελαιόλαδο, τα μη αμυλούχα λαχανικά και το τυρί. Το Δυτικού τύπου πρότυπο είχε σημαντική θετική συσχέτιση με τα κατεργασμένα δημητριακά, το επεξεργασμένο κρέας και τα ζωικά λίπη. Το Συνετό διατροφικό πρότυπο είχε σημαντική θετική συσχέτιση με τα φρούτα, τα δημητριακά ολικής άλεσης και το γιαούρτι και σημαντική αρνητική συσχέτιση με τρόφιμα τύπου fast-food. Ένα τέταρτο πρότυπο, που ονομάστηκε Βασισμένο σε Σνακ διατροφικό πρότυπο, ανιχνεύθηκε μόνο στις γυναίκες και είχε σημαντική θετική συσχέτιση με τα γλυκά, τα αλμυρά σνακ και τους ξηρούς καρπούς. Τα διατροφικά πρότυπα συσχετίστηκαν με κοινωνικο-οικονομικά χαρακτηριστικά, όπως το επίπεδο εκπαίδευσης, καθώς και με παράγοντες τρόπου ζωής, όπως το κάπνισμα. Η υψηλή προσκόλληση στο Συνετό πρότυπο συσχετίστηκε θετικά με την πρόσληψη πρωτεΐνης και ακόρεστου λίπους και αρνητικά με την πρόσληψη ενέργειας και κορεσμένου λίπους ($P \leq 0.05$ για όλα). Αντιθέτως, τα άλλα δύο πρότυπα είχαν θετική συσχέτιση με την πρόσληψη ενέργειας, ολικού και κορεσμένου λίπους. Το Παραδοσιακό πρότυπο συσχετίστηκε επιπλέον με υψηλότερη πρόσληψη μονοακόρεστου λίπους, ενώ το Δυτικού τύπου πρότυπο με υψηλότερη πρόσληψη αλκοόλ ($P \leq 0.001$ για όλα). Η προσαρμοσμένη για φύλο και ηλικία λογιστικής παλινδρόμηση, έδειξε αρνητική συσχέτιση μεταξύ του Παραδοσιακού προτύπου και της πιθανότητας παρουσίας καρδιαγγειακών νοσημάτων (OR: 0.53; 95% CI: 0.31-0.92) και θετική συσχέτιση μεταξύ του Δυτικού τύπου προτύπου και της πιθανότητας παρουσίας δυσλιπιδαιμίας (1.49; 1.08-2.05. Το Συνετό πρότυπο διατροφής δεν συσχετίστηκε σημαντικά με την πιθανότητα παρουσίας καμίας από τις υπό μελέτη εκβάσεις.

Συμπεράσματα: Δεδομένα από την πρώτη εθνικά αντιπροσωπευτική μελέτη στην Ελλάδα, έδειξαν σημαντικές συσχετίσεις μεταξύ των διατροφικών προτύπων και της παρουσίας καρδιαγγειακών νοσημάτων στον ενήλικο πληθυσμό της χώρας. Τα αποτελέσματα αυτά είναι ιδιαίτερης σημασίας για την κατανόηση των διατροφικών συνηθειών στην Ελλάδα και τον σχεδιασμό στοχευμένων πολιτικών δημόσιας υγείας για την προαγωγή της υγιούς διατροφικής συμπεριφοράς.

Επιστημονικό πεδίο: Επιστήμες Υγείας

Λέξεις-κλειδιά: διατροφή; διατροφικά πρότυπα; διατροφική πρόσληψη; καρδιαγγειακά νοσήματα; τρόπος ζωής; εθνικά αντιπροσωπευτική μελέτη; ανάλυση κύριων συνιστωσών

1. Introduction

Cardiovascular disease (CVD) is currently the leading cause of morbidity and mortality worldwide.[1,2] Despite the decreasing trend in CVD related mortality, CVD remains responsible for approximately half of all deaths in most European countries.[3] Multiple risk factors for CVD, such as obesity, hypertension and hypercholesterolemia, are well established.[4] Suboptimal diet is a leading modifiable risk factor for CVD, and a major contributor to the expected increase of CVD burden.[5,6] The "diet-heart hypothesis" is actively assessed and investigated in nutritional epidemiology during the past decades.[7] Traditionally epidemiologic studies on diet and chronic diseases have relied on analysis of specific nutrients or foods.[8] However, in real life nutrients and foods are consumed in combinations, resulting in dietary patterns. Several factors, such as cultural influences, beliefs and personal preferences, education, and other socioeconomic factors contribute to such patterns shaping.[9] Therefore, analysis of dietary data has evolved over time from focusing on foods and nutrients to focusing on diet as a whole.[9,10] Food consumption patterns have been related to multiple health outcomes, during the past decades, mainly CVD, cancer, and diabetes mellitus.[11-16] This thesis investigates the associations between empirically-derived dietary patterns, lifestyle factors and cardiovascular disease.

1.1 Identification of Dietary Patterns

Dietary patterns are multiple dietary components operationalized as a single exposure; they are measures of the total intake of food combinations in individuals and groups.[8] Dietary patterns have been increasingly used as a single exposure for several reasons, such as difficulty in distinguishing the particular effects of foods and/or nutrients due to the highly interrelated nature of dietary exposures,[17] as well as potential synergistic relationships between nutrients, which may enhance or neutralize any individual effects of single foods and nutrients.[8] Consequently, dietary patterns, which reflect entire diets, might be easier to interpret and communicate through public policies, compared to individual foods and/or nutrients.

The process of identifying, describing, and interpreting the dietary patterns of a population is affected by several methodological and analytical aspects, such as the approach used for defining the patterns (*a priori* vs. *a posteriori*), the diet assessment method used for collecting the dietary data (24-hour recall, 24hR vs. food frequency questionnaire, FFQ), and the dietary data cleaning process (e.g., accounting for energy mis-reporting).

1.1.1 Definition of Dietary Patterns

Dietary patterns are defined either *a priori* or *a posteriori* (see paragraphs 1.1.1.1 and 1.1.1.2, respectively).[8] The *a priori* approach involves the construction of patterns that reflect hypothesis-oriented combinations of foods and nutrients, whereas the *a posteriori* approach involves the application of exploratory statistical methods on collected dietary data to identify the underlying patterns.[8] Both approaches have been broadly used, yet their application is accompanied by both advantages and limitations to be considered. A third approach, namely hybrid, which is a combination of the aforementioned two methods, is also used to derive dietary patterns.[9,18] The hybrid approach is considered useful for generating hypotheses about food potential contribution to disease risk through specified causal pathways;[19] however, its application depends on the available knowledge about intermediate risk factors of the health outcome of interest,[9] hence it falls out of the purposes of this investigation.

1.1.1.1 *A Priori* Approach

The *a priori* or theoretical definition of dietary patterns is based on current nutrition knowledge or theory, and assesses adherence to a desirable predefined pattern.[8] Scores or indices of dietary quality express the overall healthiness of the diet.[8,9] These can be summary measures of the adherence degree to specific dietary recommendations, such as the Healthy Eating Index (HEI) or the Alternate Healthy Eating Index (AHEI), which were developed to measure diet quality in reference to conformance with the Dietary Guidelines for Americans.[20] Alternatively, they can be diet indices pertaining to adherence to certain dietary patterns with evidence for health benefits. The Mediterranean diet is the most characteristic example of such cases; several studies have evaluated the benefits of an *a priori* defined Mediterranean diet (e.g., the Mediterranean diet score[21,22]), and have consistently shown that higher adherence to this pattern is negatively associated with CVD risk and positively associated with longevity.[23,24]

Diet indices have several advantages. First, they summarize dietary behavior into a single score, which makes their calculation and interpretation a simple task. Second, they are easily reproducible and comparable.[9] Third, they are developed based on scientific evidence on diet-disease relationships, and, therefore, considered as useful tools to monitor overall adherence to guidelines along with the diet quality of a population. The limitations of diet indexes should also be considered. First, by design, they do not take into account, the current food habits of the population. Second, they focus on selected diet components and ignore others, hence they do not provide a measure of the overall diet quality.[25] Finally, the quality of diet indexes assessing adherence to guidelines, heavily depends on the quality of the actual guidelines.[9] Conflicts can arise when guidelines or recommendations do not have scientific consensus; theoretically defined indices often include different dietary variables and/or weightings of variables, resulting in measuring different definitions of “healthful” behavior.[26]

1.1.1.2 *A Posteriori* Approach

The *a posteriori* approach, derives dietary patterns empirically without pre-assessing their quality.[19] The identification of the empirically derived patterns is based on the actual diet of the population; it combines collected dietary data and data-driven statistical methods. The two most commonly used statistical techniques to identify the structure of existing dietary patterns in the population are principal component analysis (PCA), cluster analysis (CA) and the less commonly used factor analysis.[8,26-30]

PCA derives underlying patterns based on the interrelationships (correlation) between the dietary variables (food groups or food items). In particular, PCA takes into account the total variance of the correlations between the dietary variables and reduces the number of dietary variables to a smaller set of uncorrelated principal components (i.e., dietary patterns).[30] The components are generated sequentially; the first component accounts for the largest variance explained, the second component accounts for the second largest variance etc. Component loadings, (i.e., the correlations between the dietary variables and the extracted dietary patterns) and component scores, (i.e., the sum over all dietary variable intakes of an individual multiplied by the component loadings) are obtained.[27] At the end, each person has one score for each of the derived patterns; this score is usually different across the dietary patterns.

On the other hand, CA creates exclusive non-overlapping clusters of individuals who share similar dietary habits.[27] In particular, CA is the partitioning of a dataset into subsets (i.e., clusters), so that the data in each subset share ideally some common trait.[30] The number of clusters is pre-defined and the number of cases in each cluster is set at the final step of the analysis. Unlike PCA, in which each individual has a different score for each of the identified patterns, in CA each individual belongs to only one cluster, which represents a dietary pattern with specific food and nutrient composition.[27]

Finally, factor analysis is a statistical method used to explain variability among dietary variables in terms of fewer unobserved variables (i.e., the factors);[30] the observed variables are modeled as linear combinations of the factors, plus “error” terms. Factor analysis is often confused with PCA, yet they differ in the way dietary patterns are constructed; factor analysis identifies the common variance in the correlations between the dietary variables and estimates underlying factors (patterns) that represent groups of variables that correlate highly with each other, but not with variables outside the group.[27] In other words, the components produced by PCA are conceptualized as the linear combinations of the initial dietary variables, whereas the factors produced by factor analysis are conceptualized as the latent variables. Moreover, unlike PCA scores, factor scores vary depending on the method used to compute them.

Based on evidence from large epidemiological studies, the comparison between PCA and CA in terms of derived dietary patterns has consisting results; PCA and CA extract, in general, similar underlying patterns with small differences in their food group composition.[27,28] Importantly, although only few studies have compared dietary patterns derived from PCA and CA in terms of predicting disease outcome, these have shown that the two methods find comparable associations between similar dietary patterns and disease outcomes.[10,27,31,32]

However, PCA and CA have several conceptual differences than need to be considered before selecting one method over the other. First, the two methods answer different questions; PCA extracts underlying patterns that explain the variation in how people eat, whereas CA examines the existence of groups that eat differently.[33] Second, the eating pattern of a person is represented by only one pattern in CA, but by a combination of all patterns (different component scores) in PCA. Therefore, individuals with high score in one component may have lower scores across the rest of the component scores and, therefore, different overall eating patterns. Consequently, findings from CA may be easier to interpret. Yet, the analysis of continuous component scores, such as the ones generated with PCA, may be more powerful than categorical clusters. Finally, both PCA and CA have limitations. PCA involves a high degree of subjectivity throughout the analytical process that could result in different outcomes based on different decisions.[34] Yet, it has been shown to have reasonable reproducibility and validity,[27,28] and it is the most broadly used method to derive dietary patterns empirically. Similarly, the limitations of CA include the subjectivity in deciding how to group the dietary variables and how many clusters to create. Taking into consideration all above information, the dietary patterns were identified by PCA, in the present analysis.

1.1.2 Dietary Data Collection and Cleaning

Dietary patterns, irrespectively of *a priori* or *a posteriori* definition, are based on data gathered by individual-level diet assessment tools that attempt to measure habitual intakes; the most common tools are 24hR, dietary records, and FFQ, all of which are subjective methods that collect self-reported dietary intakes.[35] The selection of one dietary assessment method over the other is based on the study design and objectives, and on the available resources. In terms of dietary pattern identification and their association with disease outcomes, it has not been established yet which of the three tools is the best to use; all methods have limitations and are associated with different extents and types of error. Identification of energy mis-reporters is usually applied to account for measurement errors and provide better diet-disease relationship estimates.[36]

1.1.2.1 Diet Assessment Methods

In large epidemiological studies, the most commonly used dietary assessment tool is FFQ. The FFQ includes a pre-determined list of foods and asks respondents how often (predefined frequency responses) they consumed a given amount of each food over a specific time period (from 1 month to 1 year); the number of foods included in the list usually ranges from 100 to 150, although this varies across different FFQ.[37] The low administration cost combined with the limited time required for completion (20-30 minutes) make this instrument very attractive to researchers.[35,38] However, FFQ essentially includes only close-ended questions (pre-determined food list), hence it is imperative that different FFQ are developed specifically for each study group and research purposes, further accounting for diet being influenced by cultural and demographic factors, such national socioeconomic status and ethnicity.[39]

On the other hand, 24hR and dietary records collect dietary data in a more complex and costly manner that require a high level of motivation from the respondents; these methods are open-ended questionnaires that collect detailed information about all foods consumed over a specific period (ranging from 1 to 7 days usually). In particular, the 24hR is an in-depth interview collecting the detailed description (e.g., preparation method, fat content, packaging material, brand name) of all foods (and beverages) consumed during the previous day.[37] Portion sizes are estimated in reference to common size containers (e.g., cups), photographs, and/or three-dimensional food models. However, the accuracy of the data collected heavily depends on the respondent's memory and the skills and training of the interviewer.[37] Dietary records, in contrast, collect self-recorded data of the foods at the time these are consumed, thus minimizing recall bias. Common limitations among both 24hR and dietary records include unintentional alteration of dietary habits of the respondents due to self-reflection; intentional dietary intake alteration to avoid the burden of detailed responses or driven by emotions, such as guilt and shame; and complicated, time-consuming, and costly process of data collection, entry, and analysis due to the open-ended questions.

However, compared to FFQ, multiple 24hR have inherent strengths in etiologic studies with chronic diseases, despite the aforementioned limitations.[35] First, 24hR collects actual intake on specific days, whereas FFQ provides estimates of intake. Second, the recall bias may be less for 24hR as opposed to FFQ, which requires recall over a period usually as long as a year. Third, 24hR can be easily applied to diverse groups with a wide range of eating habits. Moreover, multiple 24hR allow the estimation of a population's usual intake.[37] Taking all these into consideration innovative technologies focusing on reducing the burden on the respondent and improving accuracy have been developed to improve their feasibility in epidemiological studies.[40] In spite of the major advancements observed in the dietary assessment tools with newer technologies, such as the Automated Multiple Pass Method (AMPM) for 24hR administration developed by the US Department of Agriculture (USDA)[41] and the menu-driven standardized 24hR program in the European Prospective Investigation into Cancer and Nutrition study (EPIC-Soft),[42] there is still no perfect or gold standard method for dietary intake assessment.[35]

1.1.2.2 Identification of Energy Mis-reporters

Energy mis-reporting is a common source of measurement error that is associated with all individual diet assessment methods; under-reporting is more common among food consumption surveys that use 24hR or dietary records,[43] whereas over-reporting has been primarily associated with FFQ. Moreover, under- and over-reporting of energy have been associated with demographic and socioeconomic characteristics of the participants as well as with weight status. For example, under-reporting has been associated with age, sex, educational level, and body mass index (BMI); male, elderly, with lower education, or obese individuals are more likely to under-report their energy intake.[44-47]

To achieve accurate dietary intakes, it is imperative that mis-reporting is limited to the extent possible using a standardized way. Considering the reported energy intake (EI) as a substitute measure of the total quantity of food intake, the two most common methods to evaluate the EI are based on the assumption that EI must equal the energy expenditure (EE) when maintaining a stable weight.[36,48] The first method, which is also considered as the gold standard for measuring total EE, is the doubly labeled water technique; this method is quite complex, expensive and burdensome for the participants to apply in a large-scale epidemiological study.[49]

The Goldberg cut-off method,[36,48] a simpler and less expensive method, has been proposed as an alternative way to identify potential mis-reporters of energy; this method was used in the present analysis. When the ratio of EI to the estimated Basal Metabolic Rate (BMR) is very low (or very high), the likelihood of under-(or over-)reporting is high. The cut-off values were initially developed by Goldberg to identify adult under-reporters, at individual or group level and according to the number of surveyed days, using an equation that calculates the 95% confidence limits(CI) (cut-offs) for the plausible EI;[50] the equation was later modified to correct for Physical Activity Level (PAL).[36,48] Individuals are categorized as plausible, low or high energy reporters, according to whether their EI:BMR is within, below or above the 95% CI. Various cut-off values have been used to identify mis-reporters, ranging from 0.88 to 1.53.[51-53] The process of estimating the cut-offs include (a) estimation of BMR, using the appropriate by age group and sex Harris-Benedict equations, and (b) calculation of the actual cut-offs for under-reporting (1) and over-reporting (2).

$$EI:BMR > PAL \times \exp [SD_{min} \times (S/100)/\sqrt{n}] \qquad (1)$$

$$EI:BMR < PAL \times \exp [SD_{max} \times (S/100)/\sqrt{n}] \qquad (2)$$

where PAL is the presumed average PAL for the population under study, n is equal to 1 (for data at the individual level), the standard deviation (SD) is -2 for the 95% lower confidence limit (SD_{min}) and +2 for the 95% upper confidence limit (SD_{max}), and S (3) is the overall coefficient of variation for PAL that takes into account the variability of EI and BMR.

$$S = \sqrt{[CV_{wEI}^2/d + CV_{wB}^2 + CV_{tP}^2]} \qquad (3)$$

where CV_{wEI} is the within-subject variation in energy intake, d is the number of days of diet assessment, CV_{wB} is the within-subject variation in repeated BMR measurements or the precision of estimated compared with measured BMR, and CV_{tP} is the between-subject variation in PAL. The values used for each factor were CV_{wEI}=23%, CV_{wB} for estimated BMR=8.5%, and CV_{tP}=15%.[48]

Prior epidemiological studies have shown that under-reporters tend to report higher intakes of healthy foods, such as fruits and vegetables, and lower intakes of unhealthy foods, such as high-fat and/or high-sugar foods, compared to plausible reporters.[54,55] In contrast to PCA, CA allows investigation of the distribution of low energy reporters across dietary patterns, because individuals are assigned to one cluster only; yet, findings have been contradictory as to whether low energy reporters tend to be found in a healthy or an unhealthy cluster.[56-58] The European Food Safety Authority (EFSA) suggests that mis-reporters should not be excluded, though, unless there are reasons to be considered unreliable.[43] A cross-sectional study in a nationally representative sample of adults in Sweden, assessed the impact of excluding mis-reporters on the dietary patterns derived by PCA (a similar analysis was performed for the purposes of this thesis and is presented in Paper 2);[59] they reported that effectively the identified patterns were the same.

1.1.3 Prevalent Empirically-Derived Dietary Patterns

Two dietary patterns are consistently reported in the literature; a pattern with generally healthy characteristics, commonly referred to as “Prudent”, and a less-healthy one, usually named Western/unhealthy.[8,11,12,60-62] The Prudent dietary pattern is mainly characterized by high consumption of fruit, vegetables, whole grains, fish, poultry, and low-fat items; the Mediterranean dietary pattern is also included in this wide definition.[11,13] The Western pattern is usually characterized by high intakes of red and/or processed meat, refined grains, desserts, sugar-sweetened beverages (SSBs), and high-fat products. Other dietary patterns, including those characterized by high consumption of snacks (sweet or savory),[60,63,64] and those characterized by high alcohol intake[64,65] have also been previously observed.

1.2 Determinants of Dietary Patterns

Several socio-demographic and lifestyle factors have been associated with dietary patterns.[26,66] It has been actually suggested that dietary patterns might not just represent diet, but an overall lifestyle profile.[67] Based on evidence from cross-sectional studies, age and educational level are positively associated with healthy patterns, while male gender, younger age, low educational level, low income or low occupational position have been associated with unhealthy dietary patterns.[10,66,68] Physical inactivity and smoking have been also related to Western/unhealthy patterns.[66,69,70] Large-scale prospective cohort studies, such as EPIC[71] and Nurses’ Health Study,[72] confirm these findings.

The relationship between diet and sleeping habits and quality has been mainly focused so far on individual foods and nutrients.[73] Prior findings reveal that individuals with short duration of sleep consume higher amounts of energy-rich foods and have higher energy intakes from fat and carbohydrates;[74] low protein and high carbohydrate intake have been also associated with sleep disorders, such as difficulty in initiating or maintain sleep.[75,76] Evidence on the association between dietary patterns and sleeping habits and disorders are quite limited; results have shown, though, that healthy patterns are inversely associated sleeping disorders symptoms.[77,78]

The association of dietary patterns and depression has been previously assessed, but the evidence is inconsistent;[79] a recent meta-analysis, showed that healthy patterns had an inverse association with depression likelihood, whereas unhealthy dietary patterns were associated with an increased risk of depression. Unhealthy patterns are not consistently found to have an association with depression.[80] However, the evidence suggesting that dietary patterns are associated with depression is limited, while it is primarily composed of observational studies.[81]

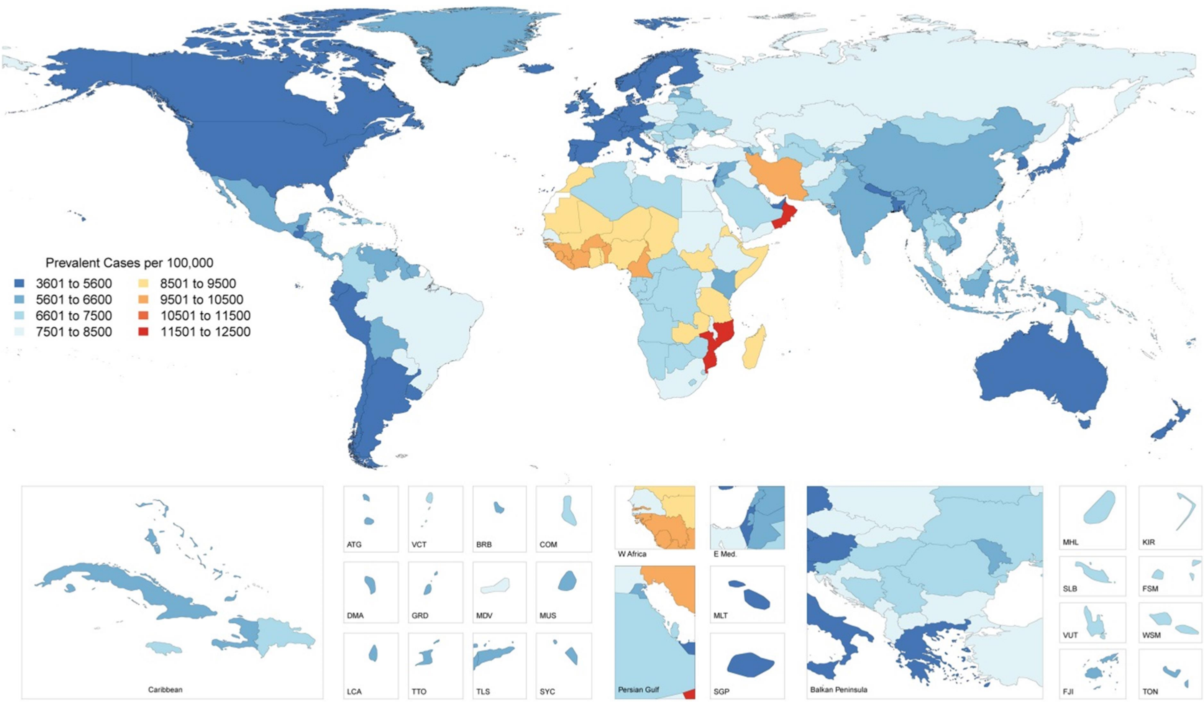
To our knowledge, in Greece, no study has described empirically-derived dietary patterns in adults in terms of socio-demographics, lifestyle factors, sleep quality, and depression. Prior studies have derived dietary patterns using PCA with or without assessing their relationship with socio-economic and lifestyle characteristics in children/adolescents, adults in a sub-national/local level, or adults with prevalent chronic disease.[82-86] The Identification of groups adhering to healthy and unhealthy dietary patterns would allow better public health policies on the promotion of healthy dietary habits.

1.3 Cardiovascular Disease

1.3.1 Definition and Prevalence of Cardiovascular Disease

Cardiovascular diseases are a set of heart and blood vessel disorders;[87] these include, among others, coronary heart disease (CHD; also called ischemic heart disease), stroke (hemorrhaging and ischemic), peripheral arterial diseases, rheumatic heart diseases, and congenital heart diseases.[88] According to the World Health Organization (WHO), there were 17.7 million deaths globally due to CVD in 2015, of which 7.4 million were attributed to CHD (i.e., myocardial infarction (MI), angina, and chronic ischemic heart disease) and 6.7 million to stroke.[88] An alarming finding is that trends in CVD mortality have plateaued for high-income regions. Yet, CVD prevalence and related death rates are not limited to a single region of the world; rather, it occurs among a subset of countries throughout Eastern Europe, Central Asia, the Middle East, South America, sub-Saharan Africa, and Oceania (**Figure 1**).[89] In fact, CVD prevalence is quite high among developing countries with 80% of CVD attributable deaths being reported in low-and middle-income countries.[3,90]

Figure 1. Age-standardized CVD prevalence worldwide in 2015.

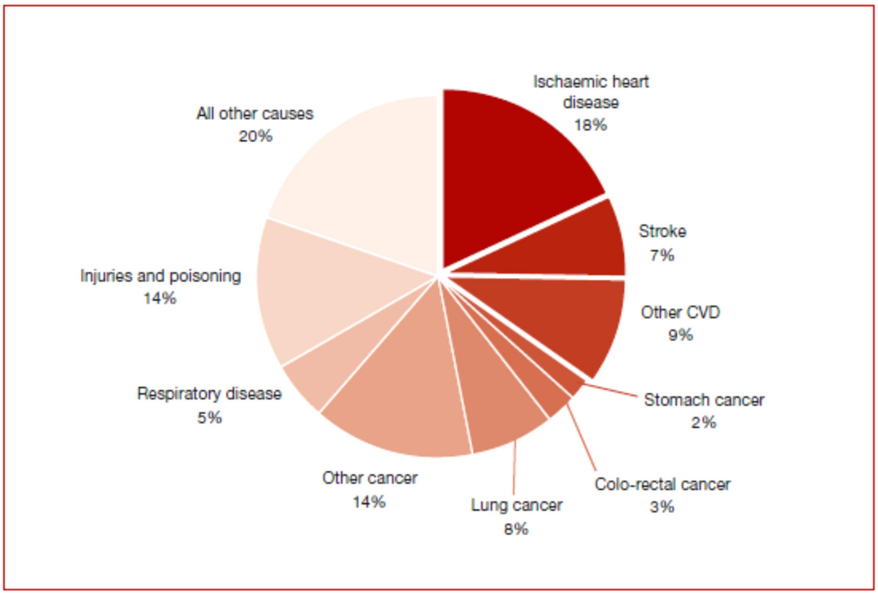


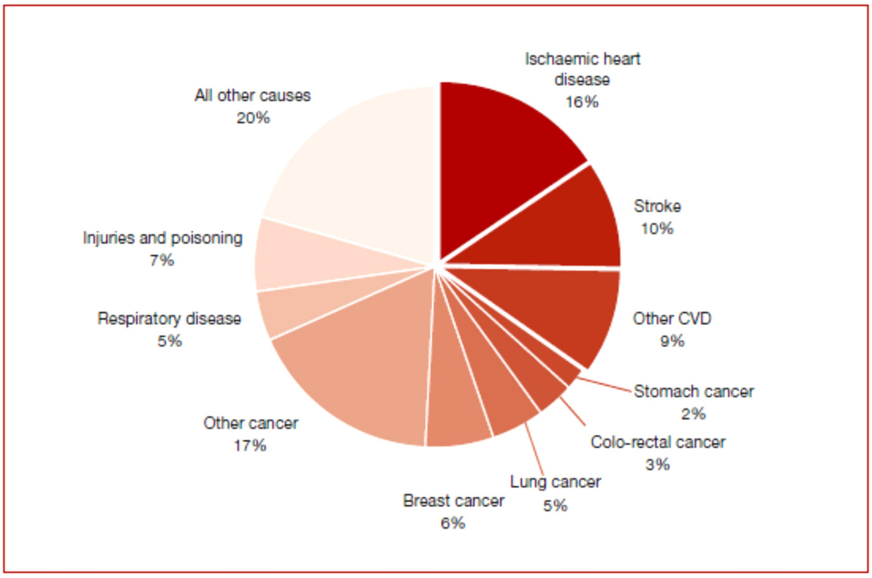
Source: Roth et al.[89]

In Europe, CVD accounts for 45% of all deaths, whereas in the European Union CVD mortality is 37%.[3] A higher CVD burden is typically reported in Central and Eastern European countries compared to Northern, Southern and Western countries (**Figure 1**). By gender, CVD is the main cause of death in men in most European countries and the main cause of death in women in all but two countries.[3] Moreover, CVD is the leading cause of premature mortality (i.e., deaths before 75 years of age) in both men and women in Europe, accounting for 35% of all deaths under 75 years each year (**Figure 2**).

Greece is not traditionally included among the countries with high CVD mortality (**Figure 1**); yet, among all causes of death, CVD is the leading cause of mortality in the country, while it accounts for almost half of deaths (48%) before the aged of 75 years.[1] Going back to the 1960s and the Seven Countries Study, Greece was found to have lower CHD incidence (fatal and non-fatal) compared to other European countries and the US.91 Since then, the influence of the Western lifestyle, reflected in the lower adherence to the Mediterranean diet and the higher preference for sedentary activities, resulted in increasing CVD prevalence.[92,93] Similarly, an increasing trend has been also reported for established CVD risk factors, such as dyslipidemia and hypertension; hypercholesterolemia, in particular, has been found to affect ~1/4 of the adult population in Greece, while the prevalence for hypertension seems to be similar (27.2%).[94]

Figure 2. Deaths under 75 years of age by cause in men and women in Europe (latest available year)





Source: Wilkins et al[3]

1.3.2 Dietary Patterns and Cardiovascular Disease Outcomes

The plausibility of the association between dietary patterns and CVD has been supported by both the *a priori* and *a posteriori* approach.[11,23,95-97] The literature generally supports a protective or harmful role for dietary patterns in total CVD risk; in particular, healthier, and usually plant-based, diets (e.g., dietary patterns rich in fruit, vegetables, and whole grains, and low in meat and refined grains) have been associated with lower CVD risk, whereas diets that are high in meat and refined grains have been associated with a higher CVD risk.[11]

In terms of specific dietary patterns, the most characteristic example for an inverse association between healthy patterns and CVD risk, is the Mediterranean diet.[23,24,97,98] The protective role of the Mediterranean diet against CVD risk has been reported both internationally and in Greece.[23,97] In addition to CVD outcomes, the Mediterranean diet has been found to be inversely associated with CVD risk factors, such as blood lipids and blood pressure.[99,100] However, unless RCTs, the majority of studies evaluating the association of Mediterranean diet and CVD, use the *a priori* approach, resulting often in different definitions of the pattern and not taking into account the component of the diet that are not already included in the indexes.[98]

The association of empirically-derived dietary patterns and CVD remains unclear. Healthy/Prudent patterns have been associated with lower CHD, and total CVD risk or mortality; yet, findings are not clear in terms of their association with risk of stroke.[11-13,101] In contrast, adherence to unhealthy patterns (e.g., Western-type pattern) has not been found to be always synonymous to increased CHD or total CVD risk.[11-13,101] In regards to CVD risk factors, findings across literature are currently inconsistent on whether Prudent/healthy patterns have a positive or inverse association with hypertension.[15] Conversely, the Western pattern does not seem to be associated with the odds of hypertension. In terms of dyslipidemia, healthy dietary patterns have been generally shown to have either no[102] or an inverse[103,104] association with total cholesterol levels. Findings for the unhealthy patterns yield contradictory results, with studies showing either a positive[105,106] or no[102,103,107] association with blood lipids. Overall, the evaluation of *a posteriori* derived dietary patterns warrant further research to fully understand their relationship with CVD and risk factors.

2. Rationale and Aims of the Thesis

2.1 Rationale and Significance

Studies evaluating the association between dietary patterns, lifestyle factors and CVD outcomes are diverse in terms of study design, study population, and dietary pattern definition. Identification of dietary patterns using PCA has grown into a popular method for studying the dietary intake of the population. In Greece, no study so far has identified empirically-derived dietary patterns in a nationally representative sample of adults, further describing them by demographic and lifestyle characteristics and assessing their association with CVD outcomes. Such analysis would provide new insights on the diverse consumption behaviors among Greek adults, and a picture of the dietary intake patterns in a period of national economic crisis. The description of individuals adhering to the dietary patterns in terms of demographic and lifestyle characteristics would facilitate plan and implementation of more focused public health policies. Furthermore, the investigation of the patterns and CVD relationship is essential to better understand the diet-disease relationship, and to predict how the population's food consumption trends will affect the country's disease burden over time.

2.2 Aims and Outline

The aims of this study were (a) to identify the main dietary patterns in a nationally representative sample of Greek adults using individual dietary data of the Hellenic National Nutrition and Health Survey (HNNHS), (b) to determine the main demographic, lifestyle, sleep, and mental health characteristics of the individuals adhering to the identified patterns, (c) to determine the food and nutrient profile of the patterns, and (d) to investigate the associations of the derived dietary patterns with CVD and CVD related medical conditions, such as dyslipidemia (i.e., high cholesterol and/or triglyceride levels) and hypertension.

The specific aims by scientific paper supporting this thesis were:

- To describe the methodology under which HNNHS was developed and conducted, including study design, sample selection process, questionnaires used for data collection, dietary data assessment instruments, as well as to provide preliminary results **(Paper 1).**
- To identify dietary patterns in the adult sample of the HNNHS (N=3,552, age range: 20-102 years) using PCA, and to determine the demographic, lifestyle, sleep, and mental health characteristics of the individuals adhering to each of the identified patterns **(Paper 2)**.
- To determine the food and nutrient profile of the derived patterns, and to investigate tha association between the patterns and dyslipidemia, hypertension CHD, and total CVD, **(Paper 3)**.

3. Methods of the Hellenic National Nutrition and Health Survey

Paper 1. Aims, Design and Preliminary Findings of the Hellenic National Nutrition and Health Survey (HNNHS)

Magriplis et al. BMC Medical Research Methodology (2019) 19:37
https://doi.org/10.1186/s12874-018-0655-y

BMC Medical Research Methodology

RESEARCH ARTICLE Open Access

Aims, design and preliminary findings of the Hellenic National Nutrition and Health Survey (HNNHS)

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Abstract

Background: The aim of the Hellenic National Nutrition and Health Survey was to assess nutritional intake, health status and various behaviors in a representative sample of the Greek population.

Methods: Data collection took place from 01.09.2013 to 31.05.2015. Random stratified sampling was performed by (a) geographical density criteria of Greece (7 regions), (b) age group of the reference population (< 19, 20–64 and > 65 years) and (c) gender distribution. The final population enrolled included (throughout Greece), 4574 individuals (42.5% men; 57.5% women of who 47.2% were from Athens metropolitan area, 18.5% from Central Macedonia, and the remaining 34% almost equally scattered throughout the country (p for the comparisons with official statistics by region, age group and sex > 0.7). Questionnaires developed were based on extensive review of the literature, following a validation procedure when necessary.

Results: Preliminary analyses revealed that 32% of the adult population were overweight and 15.5% were obese, with significant gender differences in total and per age group ($p < 0.001$, for all). The majority of the adult population reported being active smokers (50.4%) or regular alcohol consumers (72.4%); with significant gender differences ($p < 0.001$, for all). Prevalence of hyperlipidemia was 16.7%, cardiovascular disease 13.9%, hypertension 13.3%, thyroid disease 13.8%, and Diabetes Mellitus 3.6%. Significant gender and age group differences were found in various diseases.

Conclusions: Study's preliminary results provide valuable information about the Hellenic population's health. Findings from this survey could be used to detect disease risk factors for public health prevention policies and programs.

Keywords: Diet, Public health, Nutrition survey/ methods, Cross-sectional study, Greece

Background

The evaluation of current population's mental and physical health and the identification of the most important modifiable risk factors for disease prevention and treatment is mandatory in assuring a healthy and productive population [1–5].

During the last few decades, a pharmacological approach for public health promotion was widely used, hence focusing mostly on disease treatment rather than prevention. This approach allowed increased prevalence of various health risk factors, and led to an increase in health care costs, and a decrease in gross production. World data have shown that 8 out of the 20 main causes of morbidity and mortality are due to unhealthy nutrition [1, 4, 5]. Recent findings showed that the three leading factors of global disease burden were high blood pressure, smoking, and high alcohol consumption [4, 5], however when globally assessed their geographical variations on the magnitude of their effect of these risks

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varied with alcohol being the leading risk factor in Eastern Europe and high blood pressure in central Europe, for example. Additionally, overweight and obesity, physical inactivity and other modifiable risk factors (dietary fats) represent substantial risk factors too, with their risk burden varying on diseases by gender, and dietary fats by age (children, adults, elderly) [4, 5]. More specifically, older ages had a higher consumption of fish oils, while younger individuals had a higher trans-fat intake [5].

Therefore, well-designed country specific studies are necessary for the assessment and evaluation of major modifiable risk factors in different geographic regions, which will enable a focused (per region's needs) promotion of public health. Additionally, data should also focus in gender and age specific differences.

Efficiently performed well-designed nationally representative cross-sectional studies have adequately evaluated the population's health and nutrition habits. Examples from such programs include the National Health and Nutrition Examination Survey (NHANES) and the National Diet and Nutrition Survey (NDNS). During the last several decades, findings from NHANES have been used in the United States of America (USA) for status and the development of health policies to safeguard public health, including policies for prevention of lead poisoning and folic acid deficiency through compulsory food fortification [6, 7].

The present Hellenic National Nutrition and Health Survey (HNNHS) is the first national cross-sectional study that takes place in Greece, which encompasses a representative sample of all ages, and following standards established by NHANES (USA) and NDNS (United Kingdom).

The aim of the HNNHS was to assess nutritional intake, health status and various behaviors in the Greek population, which could be used to help promote public health through the design and implementation of related policies and intervention programs. In the present paper, the aims, the design and some preliminary findings of the HNNHS are explained below in detail.

Methods

Study design

This is a cross-sectional observational survey. Responders' selection was performed with a random stratified design based on the 2011 census data. Stratification was made according to (a) geographical density criteria by Greek region (7 regions), as provided by the Hellenic Statistical Authority, (b) age group of the reference population (< 19, 20–65 and > 65 years) and (c) gender distribution. A random selection of more than one individual per household was possible but no more than one individual from the same age group could be enrolled in the study. If households had children < 6 years of age, one (if more were present) was randomly selected to be included in the study, upon consent. The sample required to accurately evaluate measures of effect for common risk factors and prevalence of chronic diseases (a priori estimated to equal to 1.2), at 0.05 level (alpha) was 3634 individuals, to achieve a statistical power equal to 85%. To maintain 85% power in the estimation of prevalence rates of chronic diseases or morbidities equal to 15%, with 1 standard deviation (SD) of the referent population (N = 11,000,000), at 0.05 significance, a sample size of 4658 was needed.

Sample

Invitations were sent to approximately 6000 individuals (anticipating a 70–75% response rate) in to achieve the required sample size, based on a feasibility and volunteer basis in all Greek regions, by the study's investigators from 01.09.2013 to 31.05.2015**.** A total 4574 (42,5% men and 57.5% women) finally agreed to participate. The sample was distributed throughout Greece, with 47.2% of it residing in the Athens Metropolitan area, 18.5% in the region of Central Macedonia, whereas the rest was almost equally scattered throughout the country (Table 1; p for the comparisons with Official statistics by region, age group and sex > 0.7). Post-hoc assessment, accounting for large population (N > 10,000) resulted in a 92% study power, for an effect size of 1.2 (OR = 1.2). When the 15% probability of chronic disease was accounted for, the power was reduced to 84%.

Age standardization was performed using the 2011 Census as the reference population's data to check a-posteriori that the sampled population was representative of the Greek population, as per the aim of the study (calculations are provided in the excel file provided in the Additional files 1 and 2). The population was stratified by 10 years and statistical analyses were performed.

Table 1 Distribution of the sample within Greece

Prefecture	N	%
Attica	2160	47.2
Central Macedonia	844	18.5
Epirus	59	1.3
Eastern Macedonia, Thrace	193	4.2
Peloponnese	144	3.1
Western Macedonia	99	2.2
Thessaly	238	5.2
Central Greece	104	2.3
Western Greece	219	4.8
Crete	262	5.7
Ionian islands	51	1.1
North Aegean islands	92	2
South Aegean islands	87	1.9

The sampled population was representative for the age groups 0–19, 20–65 and 65+, and, hence were used in the analysis. Furthermore, the prevalence of chronic diseases (surveyed) of the actual Greek population (as per census), through direct standardization, was compared to the prevalence found in the study population. The crude and adjusted odds ratios (OR) calculated by age group in total and by gender did not significantly differ, hence allowing increasing generalizability of the results.

Inclusion – Exclusion criteria

Total HNNHS sample population included volunteers ≥6 months old that reside in Greece. Exclusion criteria included individuals (i), that did not speak Greek, (ii) women who were at that time breastfeeding or pregnant, (iii) members of the armed forces (including those that are currently undergoing their compulsory military service), (iv) individuals that reside in institutions (e.g. nursing homes, rehabilitation centers, hospice centers, psychiatric institutions, prisons, monasteries), (v) those that were unable to provide informed consent due to any cause (e.g., mental impairment, psychiatric condition, drug abuse, vision or hearing loss) unless a first degree relative was able to assist in the process.

Data collection

Information was collected via a series of previously validated questionnaires, from the entire population sampled (details given in "Questionnaires in brief" section). All of the questionnaire types used in HNNHS are provided in supplementary tables, along with their validation references in Additional file 1: Tables S1-S3. Additional references are listed for those questionnaires that are not relevant in this study's results.

Clinical examinations were performed on a subsample. More specifically, an initial interview took place at the volunteer's house, with the use of a specially designed computer software (i.e. Computer Assisted Personal Interview (CAPI)), to minimize response biases and misclassification (minimize volunteer burden and maximize reliability of collected data). The list of questionnaires applied can be seen in the Additional file 1: Tables S1 and S2. In summary, the interviewing process included data on (i) demographics, (ii) quality of life (QoL), (iii) medical history (i.e. chronic & autoimmune diseases, depression, anxiety), (iv) breastfeeding, (v) vitamin and subscribed drug intake, (vi) memory impairment, (vii) eating habits, (viii) alcohol intake, (ix) smoking habits, (x) physical activity, (xi) sleeping habits, (xii) overall patient health, and (xiii) effects of economic crisis. The questionnaires were chosen according to the volunteer's age, as designated by the study's protocol (Additional file 1: Tables S1-S3).

A detailed 24-h dietary recall was obtained during this process. The volunteers were also interviewed for a second 24-h dietary recall via telephone 8–20 days after the first interview, selecting a different day, and non-consecutive, as specified by HNNHS study-protocol. Specific questionnaire structure and validated food atlases for food quantification were used depending on volunteer's age (≥1.5–4 years old, ≥4- < 10 years old, ≥10- < 12 years old and ≥ 12 years old) in order to maximize response accuracy. More specifically, dietary intake data were collected using two automated multiple-pass 24-h dietary recalls and a Food Propensity Questionnaire (FPQ). To harmonize data collection, we based our food classification and description system on FOOdEx2 developed by EFSA [8], based on volunteers age (< 2 years old and ≥ 2 years old). Main differences between the two versions was the food list, (was shorter for the < 2 year old's), as well as the frequency response section. The latter referred to the frequency of food intake over the last 30 days for volunteers < 2 years old, or to the past year for those ≥2 years old. Both FPQs were developed based on the Hellenic, European and International guidelines. Overall, the methods of dietary assessment were chosen as per EFSA recommendations for the harmonization of data across countries member states of the European Union [8]. Data on eating patterns and behaviors were also collected (timing of food intake, number of meals, activities performed during food consumption, place of consumption, and others) to account for their effects on individuals weight status as studies support [9–11]. The Nutrition Data System for Research (NDSR) (developed by the University of Minnesota) was used for nutrient analysis.

At the end of the interview, volunteers were provided with a list of questionnaires (hard copy) with specific instructions, to self-complete, based on the volunteer's age and their primary response to disease state during the interviewing process (Additional file 1: Table S2). These were to be fulfilled within a specific time period, to further reduce volunteer burden (time related) and to decrease interviewer and response bias because of the nature of the nature of the questionnaires (sensitive personal information). These questionnaires included (i) qualitative FPQ (asked to be completed by all volunteers, as explained above), (ii) perceived stress scale, (iii) perception of health control, (iii) eating behavior (iv) chronic disease specific information (onset, treatment, medical follow ups, and others), (v) pregnancy and infantile information (i.e., smoking during pregnancy, number of children, weight gain per pregnancy, infant's birth weight/length, breastfeeding (type & duration), and others), (vi) environmental exposure, (vii) social readjustment factors due to the economic crisis, (viii) asthma related information, and (vi) gastrointestinal disorders (the Greek version of Rome III FGID questionnaires for both children and adults was completed).

Interview based questionnaires and those to be self-completed were addressed to volunteers ≥12 years old. Questionnaires related to volunteers, less than 12 years old, were addressed to his/her parent or primary guardian.

In the case of volunteers being unable to self-respond (i.e., with inhibiting health complications, adolescents with lack of knowledge in specific questions) a parent/ guardian was asked to assist in the interview. The economic crisis questionnaire was answered only by one adult member per household. Information on primary respondent, or on potential help received during the process was recorded ("interviewee assistant"). A small list of questionnaires where exempt from this procedure (where the main respondent has to be the volunteer himself), due to the nature of the related questions. These included questions on (i) memory impairment, (ii) screen time and alcohol use, (≥12 years - < 18 years), (iv) smoking habits (≥12 years - < 18 years) and (v) patient health questionnaire.

Completed questionnaires were handed to the participants nearest mobile unit or were given to the experienced field investigator (who performed their initial interview), when completed. To achieve a maximum response rate, the study's trained personnel performed kind reminders via phone calls. A total of 3180 volunteers (2682 adults and 498 children and adolescents) completed all questionnaires (67% in total; 71% for adults and 62.6% for children & adolescents). Field investigators completed a quality control check-list upon checking the completed questionnaires.

Blood samples were taken from a sub-sample of the population. More specifically, all participants were invited to provide blood samples for biochemical – hematological evaluation. Of them, 1197 (26.2% of total population; 28.7% of adult population) agreed; no age distribution differences were found between the total population and those who provided blood sample ($p = 0.677$). Each of these individuals visited one of the 5 mobile units where medical and anthropometrics were completed (please see Additional file 1: Table S3). All samples were collected in the morning, between 8:00 and 10:00 am, upon having fasted for at least 10 h. To assure compliance all individuals were asked if they had fasted and when their last meal was.

Experienced field investigators were from various scientific fields (dietitians, physicians, sociologists as well as dietetic and medical students), and received specialized training on the HNNHS fieldwork protocol. These specialists were involved in the development, methodology and application of study questionnaires and protocol procedure attainment was assessed with quality control testing, during field-investigation.

Ethical approval and consent form

The study was approved by the Ethics Committee of the Department of Food Science and Human Nutrition of the Agricultural University of Athens. It was also approved by Hellenic Data Protection Authority (HDPA). All members of the staff signed confidentiality agreements. Adult volunteers were asked to sign the consent form. For minors < 13 years of age the parent or primary guardian signed the form and for volunteers between 13 and 18 years of age the consent form was asked to be signed by both (parent/ guardian and volunteer).

Questionnaires in brief

All questionnaires used in HNNHS, were derived based on a priori knowledge and from components of previously validated questionnaires. For this process. The outcome of interest and previous work performed in the Greek population were also considered.

For demographic characteristics (marital status, education, health insurance, employment, income and changes in employment and/or income during the economic crisis) components from NHANES [12], Behavioral Risk Factor Surveillance System (BRFSS) study [13] and NDNS [14], questionnaires were used.

The Quality of Life (QoL) questionnaire included components of (i) QoL and chronic pain components of the Healthy Days Module developed by the Center for Disease Control (CDC) [15], (ii) questions with regards to self-reported height, weight and oral health, from the Health Survey for England and the Activity Limitations Module (also CDC developed) [16].

Two questionnaires were developed for alcohol consumption; one for minors and the second for adults. For minors (≥12 years old and < 18 years old) the questionnaire was developed based on questions from the Youth Risk Behavior Survey [17], the European School Survey Project and other Drugs [18] and the Global School-based Student Health Survey (GSHS) [19]. For the adult questionnaire data from NHANES study [12], BRFSS [13], Arkansas Cardiovascular Health Examination Survey (ARCHES) [20] and Recommended Alcohol Questions by the National Institute on Alcohol Abuse and Alcoholism (NIAAA) [21] were used. Volunteers were classified as alcohol or non-alcohol consumers, based on their intake over the past 30 days. Frequency of alcohol intake among "consumers" was categorized as daily, weekly or monthly, based on their response on (i) total drinks per month consumed, (ii) drinks per week and/or (iii) drinks per month. For minors, the total number of individuals that reported having consumed an alcoholic drink at some point in life (and not just few sips) was reported.

As in the case of alcohol consumption, smoking habits questionnaire(s) were also based on volunteer's age. In particular, for adults questionnaires used were from the NHANES [12] and BRFSS [13] studies; for minors from the Youth Behavior Survey [17], NHANES [12] and the European School Survey Project on Alcohol and other Drugs [18]. Volunteers were grouped into (i) current smokers, if they responded that they had smoked the past month, (ii) ever smokers, if they had smoked at any point in their life, and (iii) non-smokers, if they had never smoked. Frequency of smoking, among current smokers, was also recorded as “daily” or “sometimes”. Among minors, the question referred as to whether they had ever tried to smoke (aged up to 19 years).

Weight status was evaluated according to BMI. Body mass Index (BMI) is defined as the weight (in kg) over height (in meters squared). Cut-offs used (all in kg/m^2) for assessment are widely used and are the following (adults): < 18.5, underweight; 18.5–24.9, normal weight; 25–29.9, overweight; > 30, obese.

Physical activity has a well-known role as a health determinant hence the aim was to assess physical activity levels in all ages. Questionnaires on physical activity were modified based on age groups as per a priori knowledge, including (i) ≥2- < 12 years old of the questionnaire was based on questions from the NHANES survey [22] and Preschool-aged Children Physical Activity Questionnaire (Pre-PAQ Home Version) [23] (ii) ≥12- < 18 years old, the International Physical Questionnaire – Adolescents (IPAQ-A) [24], (iii) ≥18 years- < 65 years old the IPAQ short form was used [25] and (iv) for ≥65 years of age a modified version of the IPAQ has been suggested [26]. Preliminary results reported in this study include level of physical activity as perceived by the adult volunteers (sedentary, low, moderate and active) or by the primary care giver if the volunteer was < 12 years old.

Information about medical history for disease prevalence among the Greek population, related medical treatment and insurance coverage were collected. The synthesis of this questionnaire was based on the National Health Survey, NHANES [12], ARCHES [20], and the Million Women Study [27]. The definition of clinical investigated outcomes was based on the International Classification of Diseases (ICD)-10th version, recorded by experienced study investigators. Diabetes was defined as fasting blood glucose> 125 mg/dl or if on diabetic medication; dyslipidemia if total triglycerides> 150 mg/dl and/or total cholesterol> 200 mg/dl or on lipid-lowering medication; hypertension as average blood pressure greater or equal to 140/90 mmHg, or on antihypertensive treatment.

Further details on specific disease states (hypertension, dyslipidemia, diabetes) with specific questionnaires [20], were collected once the volunteer declared as having such a condition. In particular, data on prevalence of Chronic Obstructive Pulmonary Disease (COPD) was obtained using the COPD Population Screener [28] and Asthma using the questionnaire from the Hellenic Thoracic Society (for adults), and the Greek version of the questionnaire International Study of Asthma and Allergies in Childhood (ISAAC) [29] (minors 6–18 years old). Following a literature review the Rose Questionnaire for Angina [30] and the Edinburgh Claudication Questionnaire were used in HNNHS [31].

Additional the types of questionnaires used in the study can be viewed in the Additional files 1 and 2 and they included information on breastfeeding, drug and supplement use, memory impairment (≥45 years old), eating habits and behavior (as previously reiterated), sleeping habits, data on depression, stress (acute and chronic) & health locus of control, gestational & childbirth related questions, environmental exposure, functional gastrointestinal disorders, vitamin D intake status & sun exposure, and economic crisis, to acquire adequate and substantial information on the population’s exposures and risks. Details for each of these questionnaires will be provided upon analysis.

Clinical/ physical evaluation and biochemical variables

HNNHS also included physical examination (temperature, spirometry, blood pressure, etc.), anthropometry (weight, height, waist and hip circumference, body composition, and grip strength), and several blood tests (glucose, HbA1c (diabetics), insulin, total lipid profile, thyroid hormones, thyroglobulin, PTH, complete blood count, folic acid, iron, ferritin, B_{12}, 25OH-vitamin D, creatine, urea, albumin, total protein, ALT, AST, bilirubin, uric acid, calcium, magnesium, manganese, selenium, hs-CRP, cortisol, and heavy metals, namely As, Cd, Co, Hg, Mo, Pb, Pt, Sb, W, Zn, Ce, La, Th, U) in a subsample of the population, to examine correlations with various health indices in later analyses (Additional file 1: Table S3).

Statistics

Prior to analysis, data were cross checked for missing values and outliers. Missing information was corrected if the information was derived from other questionnaires and/or measurements (non-reported values of weight and height were completed if the individual was measured at the CAPI). Also, individuals responding as non-diseased but reported taking a disease related medication, were classified as with disease outcome. Baseline socio-demographic are presented as frequencies and percentage (N, %) per gender. Variables of interest are presented in total and per gender and age-group (i.e., population’s weight status, smoking, alcohol, physical activity, prevalence of chronic disease), while physical activity is presented by specific age groups (as per questionnaires). Chi-square test was used to assess gender differences by age group for weight status, smoking and alcohol intake, and for total prevalence of chronic disease by gender. Tukey's paired means test was used to detect differences between age groups (for each chronic diseases). All reported *p*-values were based on two-sided hypothesis tests, with significance level at 5%. The statistical models were computed using STATA 12.0 (STATA corp. Texas).

Results

Demographic data

The sample was distributed in all different regions of Greece (Table 1). 47.2% was in the region of Attica, 18.5% Central Macedonia, and the rest of the sample being scattered through various regions of Greece (1.3% Epirus, 4.2% Eastern Macedonia and Thrace, 3.1% Peloponnese, 2.2% Western Macedonia, 5.2% Thessaly, 2.3% Central Greece, 4.8% Western Greece, 5.7% Crete, 1.1% Ionian islands, 2% North Aegean and 1.9% South Aegean).

The total number of participants is 4574 volunteers of which 1943 were males and 2629 females. Table 2 shows distribution per gender, age and socioeconomic parameters. Age distribution was representative of the 2011 Census, with 19% ($N = 869$) of the sampled population being 0–19 years old, 67% ($N = 3064$), 20–64 years old, and 14% ($N = 639$) were ≥ 65 years old. Marital status was as follows: 40.6% of the population was unmarried (43.3% males and 38.5% females), 48.4% married (51.4% males and 46.4% females) and 0.1% having a cohabitation agreement 6.2% were widowers (2.2% males and 9.2% females), 3.8% divorced and 0.7% separated.

Educational level greatly varied with approximately 32% having a University degree or greater, 7.1% had completed secondary education. Approximately 17% of the population had limited to low education, 27.1% completed lyceum (12 years of schooling), 5% technical secondary school and 8.3% private post-lyceum college. A large percentage of the population (78.3%; 77.8% males and 78.8% females) reported having public health insurance whereas only 4.3% had private insurance and 8.9% both types. A total of 8% males and 6.2% females were not insured (Table 2).

In terms of net monthly income (Table 2), 13,5% had low income (<€300–850), 11.4% had €851–1050, approximately 18% had moderate high income (€1051–1500), 10.6% had €1501–1900, 9.1% had €1901–2400, and 10.7% had high income (€2401–3800 and > €3801).

Weight status and behavioral data

Sample's self-reported weight status in total by age group (> 20 years old) and gender based on Body Mass Index (BMI) can be found in Table 3. A total prevalence of 47.5% of the adult population was overweight (32%) and obese (15.5%), with the prevalence increasing with age in both genders. A significant body weight status difference was found in each age group, with males having a higher prevalence of overweight compared to females ($p < 0.001$) in all age groups.

Frequency of alcohol consumption among adults was 72.4% (Table 4), with approximately 7% reporting daily consumption, 33% weekly and 60% on a monthly basis. A significant greater percentage of males reported of being alcohol consumers than females (81.1% compared to 67%, respectively; $p < 0.001$) and being more frequent alcohol consumers as well ($p < 0.001$). Among minors (12 to 19 years of age, inclusive), 111 out of 340 individuals (32.6%) reported as having consumed an alcoholic drink at some point before, and not only a few sips (Table 4). No significant differences were found between genders among minors in alcohol consumption ($p = 0.121$).

Smoking frequency in the total population among adults and minors, per gender, is being shown in Table 5. Approximately 34% of the population were current smokers, whereas 50.9% reported on having smoked at some point in their life. Significant gender differences were found in both cases with a higher proportion of males reporting to have smoked (59% compared to 44%) or of being current smokers (38.3% compared to 30.8; $p < 0.001$ for all). Among current smokers 87.3% reported to smoke daily with a borderline difference found between genders ($p = 0.046$). A total of 22% of minors (up to 19 years of age, inclusive) reported of having tried to smoke at some point. No significant gender differences were found ($p = 0.229$).

Preliminary results of physical activity level were self-reported as sedentary, low activity, moderately and very active (Table 6). The highest proportion of the population being very active was in young children (2–12 years old, 68.6%) and among adolescents (48.5%). Twenty – 5 % (25%) of adults aged 18–65 and > 65 years old reported being very active whereas 20% of the elderly (> 65) reported of having a completely sedentary lifestyle.

Prevalence of chronic disease

In Table 7, the prevalence of various chronic diseases is presented in total and per age group (20–39, 40–64, and 65+) in adults. In each category, gender specific rates can also be viewed. The highest prevalence (16.7%) was reported for hyperlipidemia (increased cholesterol or triglycerides), with prevalence increasing in both genders with age (Tukey's test $p < 0.001$ between groups). The same pattern was found for hypertension with the prevalence mounting to 56% (51.2% in males, 61% in females; $p < 0.05$) in the elderly compared to 1.7% in adults aged 20–39 and 17.3% in the 40–65 age group (Tukey's test not significant). Accordingly, age patterns were seen in all CVD (CHD, angina, MI, heart failure, arrhythmia and stroke), with significant age group differences found only

Table 2 Volunteer baseline socio-demographic characteristics by gender

	Males		Females	
	N	%	N	%
	1943	42.5	2629	57.5
Age				
0–19	426	21.9	443	16.9
20–64[a]	1259	64.8	1805	68.7
20–39	*797*	*41.0*	*1040*	*39.6*
40–65	*462*	*23.8*	*765*	*29.1*
65+	258	13.3	381	14.5
Marital status				
Unmarried	841	43.3	1012	38.5
Married	998	51.4	1217	46.3
Cohabitation agreement	2	0.1	2	0.1
Widower	43	2.2	241	9.2
Divorced	47	2.4	127	4.8
Separated	10	0.5	23	0.9
Don't know	–	–	1	0
Refused	–	–	4	0.2
Educational level				
No or little education	25	1.6	90	4
Primary school	128	8.2	224	9.9
Gymnasium	81	5.2	99	4.4
Lyceum	418	26.7	621	27.3
Technical school	133	8.5	57	2.5
Private college (Post Lyceum)	114	7.3	204	9
University degree (AEI)	336	21.5	517	22.7
University degree (TEI)	144	9.2	219	9.6
Master's degree	109	7	188	8.3
PhD	31	2	22	1
Refused	4	0.3	3	0.1
Net monthly income (€)				
≤ 300	76	3.9	106	4
301–650	148	7.6	285	10.8
651–850	171	8.8	264	10
851–1050	237	12.2	283	10.8
1051–1250	172	8.9	236	9
1251–1500	178	9.2	237	9
1501–1900	222	11.4	264	10
1901–2400	183	9.4	231	8.8
2401–3800	177	9.1	202	7.7
> 3801	51	2.6	59	2.2
Don't know	122	6.3	214	8.1
Refused	204	10.5	246	9.4
Health insurance				
Uninsured	156	8	162	6.2
Insured, private	91	4.7	105	4
Insured, public	1511	77.8	2071	78.8
Insured, both private and public	157	8.1	252	9.6
Don't know	10	0.5	20	0.8
Refused	4	0.2	3	0.1

[a]The sampled population (N%) in the age group 20–64, was further categorized to 20–39 years and 40–65 to cross-reference with further analysis performed in these sub-categories

in heart failure (Tukey's test $p = 0.014$ for 65+ compared to 20–39 years). Diabetes prevalence and osteoporosis was also considerably higher in the older age group (16,8%) compared to 3.8% in total population and 16.2% compared to 5.4%, respectively. Only osteoporosis was significantly different between age groups ($p < 0.001$ for 65+ and 20–39 and 40–64). The prevalence of thyroid disease was high in all age groups, especially in females and significantly different between the 65+ and 20–39-year-old age groups (Tukey's test $p = 0.026$). A significant difference was also found in cancer prevalence between the older and younger adult age groups (Tukey's test, $p = 0.033$).

Gender differences and chronic disease

Significant gender differences were found in hyperlipidemia, arrhythmia, cancer, thyroid disease, osteoporosis, arthritis/rheumatoid arthritis, irritable bowel syndrome, depression, and chronic stress, with females having a significantly higher proportion in each one of them. Prevalence of asthma and cancer was also higher in females, more specifically in the 40–64 age group (4.8% vs. 1.7%; $p < 0.05$ and 3.7% vs. 0.6%; $p < 0.01$, respectively). Gender difference was also found in CHD with males having a higher prevalence in the total adult sample and in the older group ($p < 0.001$, for all). The prevalence of MI did not differ in the total sample but was significantly higher in males over 65 years old than females in the same age group (9.1% vs. 1.9%; $p < 0.001$). Diabetes mellitus was significantly higher in males aged 40–64 years old than females of the same age group (5.9% vs. 2.7%; $p < 0.01$).

Discussion

The HNNHS was set up in 2013 with the aim to provide comprehensive, nutrition and health information, on a representative sample of the Greek population. Preliminary results of the HNNHS study showed an elevated

Table 3 Population's weight status in total by age group and gender based on Body Mass Index (BMI) categorization

Weight status categorization[d]	Total		By age group[e] and gender					
	Total adult population[e]		20-39[a]		40-64[b]		65+[c]	
			N (%)		N (%)		N (%)	
	N	%	M	F	M	F	M	F
Underweight	175	4.7	12 (1.5)	88 (8.5)	5 (1.1)	25 (3.3)	8 (3.1)	37 (9.8)
Normal weight	1772	47.9	420 (52.7)	722 (69.5)	139(30.2)	335 (43.8)	60 (23.3)	94 (24.8)
Overweight	1183	32.0	285 (35.8)	160(15.4)	212 (46.0)	244 (31.9)	127 (49.2)	154 (40.6)
Obese total	572	15.5	80 (10.0)	69 (6.6)	105 (22.8)	161 (21.1)	63 (24.4)	94 (24.8)

N (%) Frequency (percentage), *M* males, *F* Females
By gender: % of males or females in question compared to total number of males or females, respectively
[a]Chi square test for difference in weight status between genders in 20–39-year-old group ($p < 0.001$)
[b]Chi square test for difference in weight status between genders in 40–65-year-old group ($p < 0.001$)
[c]Chi square test for difference in weight status between genders in 65+ year-old group ($p < 0.006$)
[d]Based on BMI (kg/m^2) categorization: < 18.5 = underweight; 20–25 = normal weight; > 25–30 = overweight; > 30 = obese
[e]Study population ≥ 20 years of age; Chi square test for difference in weight status between age groups in total ($p < .001$) and per gender ($p < .001$)

prevalence of overweight and obesity in adults as well as dyslipidemia and hypertension. Among the adult population prevalence of overweight & obesity was almost 47%, significantly varying by gender, 17% of the total population had dyslipidemia, 13% hypertension and about 4% had diabetes and 14% were affected by a form of thyroidism. All outcomes significantly increased with age with prevalence of dyslipidemia and hypertension reaching 45 and 57% in the elderly, respectively. Furthermore, the prevalence of osteoporosis in Greek women over 65 year of age was 25.8%, a disease that is highly preventable.

In more detail, prevalence of overweight and obesity as well as chronic diseases increased with age with males having overall a higher weight status than females. This is in accordance with data from NHANES showing increased levels of obesity in adults, by sex, age and ethnicity. Hyperlipidemia prevalence in 2011 in Greece was 15% [32], and results from the ATTICA study reported that 1 in 2 adults (45 ± 15) years old was dyslipidemic [33].This is in accordance with current results from HNNHS (44,8% in total; 39.9% in males and 48.3% in females). High levels of hypertension and hyperlipidemia were also found in other studies [34, 35]and policies targeting the reduction of these public health outcomes are warranted as were developed by other countries upon findings [34, 35]. Participation rate was higher in females than males, as has been reported in most European countries [36].

Table 4 Frequency of alcohol consumption habits in minors and adults in total and by gender

Adults (20+ years)	Alcohol consumption*						
	Total		Males		Females		Level of significance [a]
	N	%	N	%	N	%	
The past 30 days*							
No	998	26.9	285	18.8	713	32.8	$p < 0.001$
Yes	2685	72.4	1229	81.1	1454	67.0	
Frequency							
Everyday	183	6.8	128	10.4	55	3.8	$p < 0.001$
Weekly	874	32.6	456	37.1	418	28.8	
Monthly	1628	60.6	645	52.5	981	67.5	
Minors (12–19 years) **							
Ever consumed							
No	229	67.4	142	89.3	153	84.5	$p = 0.121$
Yes	111	32.6	17	10.7	28	15.5	
Don't know	1	0.5					
Refused	–	–					

*For adults (20 + years of age: $N = 3705$ in total, 7 missing): any alcohol consumption the past 30 days and frequency of consumption
**For minors (12–20 years of age, $N = 340$, 159 males and 181 females): whole alcoholic drink consumed at some point in life (and not just few sips). 66 minors were < 18 years and 45 18 &19 years old
[a]Tested via chi square test for gender differences in adult population (20 years +) and in minors (up to 19 years); *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$;

Table 5 Frequency of smoking habits in total population among adults and minors by gender

Adults (20+ years)	Smoking**						
	Total		Males		Females		Level of significance[b]
	N	%	N	%	N	%	
Ever smoked							
No	1935	52.4	620	41.0	1215	56.0	$p < 0.001$
Yes	1878	50.9	893	59.0	955	44.0	
The past 30 days*							
No	2433	65.7	934	61.5	1497	68.5	$p < 0.001$
Yes	1252	33.8	580	38.2	672	30.8	
Frequency							
Every day[a]	1093	87.3	519	89.5	574	85.4	$P = 0.046$
Some days[a]	158	12.6	60	10.3	98	14.6	
Don't know	1	0.1					
Refused	–	–					
Minors (10–19 years)							
Ever smoked							
No	100	76.3	33	70.2	67	79.8	$p = 0.229$
Yes	29	22.1	12	25.5	17	20.2	
Don't know	1	0.8					
Refused	1	0.8					

*For adults (> 19 years of age: 3705 in total): ever smoking; for minors specified if they even tried it (then response yes)
[a]For adults smoking the past 30 days (frequency (%) of smoking for smokers $N = 1252$)
[b]Tested via chi square test for gender differences in adult population (20 years +) and in minors (up to 19 years); *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$;

The proportion of alcohol consumption and current smoking status was high, although the latter, prevalence of smoking, was lower compared to previous findings in the Hellenic population [37]. An alarming proportion of minors had tried alcohol or had smoked at some point. Smoking is a known risk factor for many chronic diseases, including cardiovascular disease, many forms of cancer, asthma and COPD. Alcohol, although has been found to have protective effects on CVD, when consumed in moderation [38], it is forbidden in minors.

Regarding arterial hypertension, the present study's preliminary results are comparable with other studies where hypertension was self-reported (13.1% vs. 13.3%, respectively, $n = 5003$) [39]. As hypertension is a common risk factor of cardiovascular disease, data on level of awareness is warranted. Efstratopoulos et al., found an awareness level of 60.2% among Greek hypertensive individuals [40], therefore, further investigation is warranted. The prevalence of hypertension in the NHANES study, for those ≥20 years old was also close to the EPIC and HYPERTENSHELL studies (33.5%) [41]. A 4% prevalence of diabetes mellitus was found in this study, reaching 6.3% for adults over 30 years of age, compared to 7–11% prevalence reported in Greece among adults [33, 42, 43]. HNNHS included information on thyroid and renal function, for which there are no data available in the Greek population. Respective prevalence levels of 13.7 and 0.6% of those ≥20 years old were reported. The increased prevalence in all types of thyroid

Table 6 Physical activity levels among different age groups based on self-reported data

Physical activity*	≥2 - < 12 years		≥12 - < 18 years		≥18 - < 65 years		≥65 years old	
	N	%	N	%	N	%	N	%
Sedentary way of life	–	–	–	–	–	–	128	20
Low activity	15	3.2	24	11.7	584	18.3	117	18.3
Moderate active, average	126	26.7	74	35.9	1357	42.4	205	32.1
Very active	324	68.6	100	48.5	812	25.4	160	25
Don't know	–	–	1	0.5	2	0.1	1	0.2
Refuse to respond	–	–	–	–	2	0.1	–	–

*Individuals were asked to report their perceived physical activity status or to state their child's if they responded on their behalf

Table 7 Prevalence of chronic disease in adult population sampled, in total, by gender and by gender and age group

Presence of disease/condition	Total				By gender and age group[a]					
	Total sample		By Gender[b] N (%)		20–39 N (%)		40–64 N (%)		65+ N (%)	
	N	%	M	F	M	F	M	F	M	F
Increased cholesterol or triglycerides[c]	765	16.7	297*** (15.2)	468 (17.8)	62** (7.8)	48 (4.6)	127 (27.6)	226 (29.5)	103* (39.9)	183 (48.3)
Don't know	175	3.8								
Hypertension	608	13.3	241 (12.4)	367 (14.0)	21* (2.6)	11 (1.1)	88 (19.1)	124 (16.2)	132* (51.2)	231 (61.0)
	47	1.0								
Coronary Heart Disease	69	1.8	53*** (3.4)	16 (0.7)	0 (0)	1 (0.1)	17 (3.7)	1 (0.1)	36*** (14.0)	14 (3.7)
Don't know	32	0.8								
Angina	36	0.9	19 (1.2)	17 (0.8)	6 (0.8)	4 (0.4)	6 (1.3)	2 (0.3)	7 (2.7)	10 (2.6)
Don't know	31	0.8								
Myocardial Infarction (Heart attack)	49	1.3	37 (2.4)	12 (0.5)	0	0	16** (3.3)	5 (0.7)	21*** (8.1)	7 (1.9)
Don't know	13	0.3								
Heart failure	42	1.1	16 (1.0)	26 (1.1)	0	3 (0.3)	2 (0.4)	8 (1.1)	14 (5.0)	15 (4.0)
Don't know	27	0.7								
Arrhythmia	295	7.7	91** (5.8)	204 (9.0)	21 (2.6)	48 (4.6)	25 (5.4)	71 (9.3)	45 (17.4)	78 (20.6)
Don't know	42	1.1								
Stroke	41	1.1	18 (1.1)	23 (1.0)	1 (0.1)	2 (0.2)	3 (0.7)	4 (0.5)	14 (5.4)	17 (4.5)
Don't know	11	0.3								
Cancer	53	1.2	14** (0.7)	39 (1.5)	3 (0.4)	1 (0.1)	3** (0.6)	28 (3.7)	8 (3.1)	10 (2.6)
Don't know	8	0.2								
Diabetes (Type I & II)[d]	162	3.6	73 (3.8)	89 (3.4)	3 (0.4)	4 (0.4)	27** (5.9)	21 (2.7)	42 (16.3)	64 (16.9)
Don't know	24	0.5								
Thyroid (any type of condition)[e]	629	13.8	93*** (4.8)	536 (20.4)	36*** (4.5)	160 (15.4)	26*** (5.6)	248 (32.4)	24*** (9.3)	113 (29.8)
Don't know	102	2.2								
Asthma	184	4.0	69 (3.6)	115 (4.4)	40 (5.0)	48 (4.6)	8* (1.7)	37 (4.8)	6 (2.3)	20 (5.3)
Don't know	16	0.4								
Chronic Obstructive Pulmonary Disease (COPD)	63	1.6	25 (1.6)	38 (1.7)	5 (0.6)	8 (0.8)	9 (2.0)	15 (2.0)	11 (4.3)	15 (4.0)
Don't know	77	0.6								
Chronic kidney disease	27	0.6	13 (0.7)	14 (0.5)	3 (0.4)	1 (0.1)	2 (0.4)	4 (0.5)	8 (3.1)	9 (2.4)
Don't know	3	0.1								
Osteoporosis[f]	206	5.4	13*** (0.8)	193 (8.3)	1 (0.1)	3 (0.3)	4*** (0.9)	95 (12.3)	8*** (3.1)	95 (25.8)
Don't know	79	2.1								
Arthritis/ Rheumatoid disease	324	7.1	65*** (3.3)	259 (9.9)	9* (1.1)	23 (2.2)	28*** (6.1)	106 (13.9)	28*** (10.8)	128 (33.8)
Don't know	83	1.8								
Crohn's disease or Ulcerative colitis	16	0.4	6 (0.3)	10 (0.4)	2 (0.2)	3 (0.3)	1 (0.2)	6 (0.8)	3 (1.2)	1 (0.3)
Don't know	6	0.1								
Irritable Bowel Syndrome (IBS)	317	6.9	53*** (2.7)	264 (10.1)	25*** (3.1)	105 (10.1)	18*** (3.9)	121 (15.8)	9* (3.5)	35 (9.2)

Table 7 Prevalence of chronic disease in adult population sampled, in total, by gender and by gender and age group *(Continued)*

Presence of disease/condition	Total				By gender and age group[a]					
	Total sample		By Gender[b] N (%)		20–39 N (%)		40–64 N (%)		65+ N (%)	
	N	%	M	F	M	F	M	F	M	F
Don't know	46	1.0								
Depression	180	4.2	42*** (2.3)	138 (5.6)	15 (1.9)	33 (3.2)	12*** (2.6)	62 (8.1)	15 (5.8)	42 (11.1)
Don't know	63	1.5								
Chronic Stress	495	11.6	128*** (7.1)	367 (14.9)	56*** (7.0)	143 (13.8)	42*** (9.1)	134 (17.5)	25** (9.7)	78 (20.6)
Don't know	39	0.9								

By gender: % of males or females who reported as having the outcome in question compared to total number of males or females, respectively
By age-group: Number of outcomes reported per gender in each age-group (%)
[a]Tested via chi square test for gender differences by age group
[b]tested via chi square test for gender differences in total sample; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$
[c]3.5% of the sample replied that they do not know for cholesterol; < 1% for hypertension, coronary heart disease, angina, myocardial infarction (0.3), stroke (0.3), heart failure,; arrhythmia (1.1%), diabetes (0.53), 2.2% for any thyroid disease, asthma (0.35%), chronic obstructive pulmonary disorder (0.63%). Kidney failure (0.1%), 2.1% for osteoporosis, 1.8% for arthritis, 0.1% for Crohn's disease, 1.0% for irritable bowel syndrome, 1.5% for depression, 0.91% for chronic stress
[d]Prevalence for type I diabetes: 3/4754
[e]0–19 age group: for thyroid disease: Males (1.6%) and females (3.4%); For asthma: Males (3.5%), Females (2.3%); For chronic stress: Males 1.55%, females 4.3%
[f]Out of which 13 osteopenia

conditions (hypothyroidism, hyperthyroidism, Hashimoto thyroiditis), especially among women, underlies the value of HNNHS and stresses the need to further investigate risk factors linked to this outcome, such as iodine and vitamin D status, as well as nutritional intake and search for deficiencies. The prevalence of cardiovascular disease, the leading cause of mortality worldwide, found in the study population was 13.9%, in total. This included 7.7% of the total sample that reported having arrhythmia, 1.8% coronary heart disease, 1.3% myocardial infarction, 0.9% angina, 1.1 heart failure, and 1.1% had suffered a stroke.

Furthermore, an increased level of stress-associated disorders including chronic perceived stress (11.6%), depression (4.2%), Crohn's disease (0.4%) or ulcerative colitis (0,4%), and irritable bowel syndrome (6.9%) were found. These outcomes may be associated with the economic crisis seen in Greece over the past years but can also be linked to various nutritional and behavioral factors, that need to be examined. Interestingly, data with regards to perceived change in household budget show that most volunteers perceived change being more severe in 2012 (23.2%) than 2011 (18.3%) and 2013 (12.6%). Details that may have affected these stress-associated disorders, remain to be investigated.

Limitations
Due to the cross-sectional nature of the study, no causal relationships can be formulated. Also, the data presented and analyzed in this first report are from reported data. However, experienced field investigators checked the data and recorded clinical outcomes based on ICD-10th version codes. Furthermore, sensitive personal questions, were self-completed to decrease reporting bias. All clinical outcome data were further cross-checked with other related questions, ie, medications, in order to accurately code the participants and decrease misclassification. Reporting of data in more depth and comparison with other past small, non-nationally representative surveys in Greece are beyond the scope of this first methodological publication and will be described elsewhere.

Strengths
Health surveys as HNNHS can reveal target groups in need for prevention strategies according to educational level, employment and marital status, area of residence in a subnational level, and health behavior [40, 44]. HNNHS, is the first national representative study performed in Greece to assess nutrition and health status of the population including all age groups. Questionnaires used were constructed after performing an extensive literature review and based on other validated questionnaires that have been used in other large national studies and in the Greek population. Another strength is the synergistic action of multiple health care specialists in study design, filed work and data analysis. Furthermore, the use of the especially designed computer software, CAPI, increases reliability of collected data, since it reduces response bias, misclassification and volunteer burden. Measurements, clinical assessment and blood tests performed in a subsample of the population will be used to further validate the preliminary results presented here.

Conclusions
The HNNHS study aims to evaluate the health of the Greek population. The data presented provide a preliminary overview of demographic and lifestyle data of the population. We envision that this study will provide valuable information regarding the health of the Greek population and that it will become a rolling program that will facilitate the development and evaluation of public health policies addressing key risk factors that impact on the health of the Greek population.

Additional files

Additional file 1: **Table S1.** List of questionnaires applied to volunteers according to age during the initial interview. **Table S2.** List of questionnaires to be self-completed at home, according to age. **Table S3.** List of exams and questionnaires applied to volunteers, according to age, during their visit to the mobile unit. (DOCX 38 kb)

Additional file 2: 3 worksheets (All, Males, Females) for age adjusted chronic disease calculations, standardized by Hellenic population distribution (2011 Census). (XLSX 35 kb)

Abbreviations

ARCHES: Arkansas Cardiovascular Health Examination Survey; BRFSS: Behavioral Risk Factor Surveillance System; CAPI: Computer Assisted Personal Interview; CDC: Centre for Disease Control; CHD: Coronary Heart Disease; COPD: Chronic Obstructive Pulmonary Disease; CVD: Cardiovascular disease; DM: Diabetes Mellitus; EFSA: European Food Safety Authority; EPIC: European Prospective Investigation into Cancer and Nutrition; FGID: Functional Gastrointestinal Disorders; FPQ: Food Propensity Questionnaire; GSHS: Global School-based Student Health Survey; HDPA: Hellenic Data Protection Authority; HNNHS: Hellenic National Nutrition and Health Survey; IPAQ: International Physical Activity Questionnaire; ISAAC: International Study of Asthma and Allergies in Childhood; MI: Myocardial Infarction; MRC: Medical Research Council; NatCen: NatCen Social Research; NDNS: National Diet and Nutrition Survey; NDSR: Nutrition Data System for Research; NHANES: National Health and Nutrition Examination Survey; NIAAA: National Institute on Alcohol Abuse and Alcoholism; OR: Odds ratio; QoL: Quality of Life; USA: United States of America

Acknowledgments

The study was co-funded by Greece and the European Union (European Social Fund) under the Operational Program "Human Resources Development 2007-2013".

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Funding

The study was co-funded by Greece and the European Union (European Social Fund) under the Operational Program "Human Resources Development 2007–2013".

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

AZ conceptualized, designed and was the Principal Investigator of the study. AZ and RM coordinated the design of the data collection instruments, coordinated and supervised data collection. GM supervised medical data collection. ID, DK, AVM and IB were involved in every step of the study and made substantial contributions to the design and methodology of data collection as well as the acquisition of data and training of field workers. TN coordinated mobile unit data collection. SMT and KA contributed to the mobile unit data collection and analysis. DBP coordinated sample collection methodology. ID drafted the manuscript equally with EM. EM also supervised the design and the preparation of the data base and carried out the statistical analyses and revised the manuscript. GD, CG, EF, EMT, ET, TES, AV, ES, MC, AK, GK, SZ and AP contributed to parts of methodology. All the authors approved the final manuscript as submitted. Contributors: EF, ET, TS, AV, ES, MC, AT, GK, SZ, AP contributed to the writing of the protocols and the data collection on the field. All contributors approved the final manuscript as submitted. Advisory Committee: GC, GD, GD, IM and ER acted as external advisory committee. All the Advisory Committee members approved the final manuscript as submitted. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The study was approved by the Ethics Committee of the Department of Food Science and Human Nutrition of the Agricultural University of Athens. It was also approved by Hellenic Data Protection Authority. All members of staff signed confidentiality agreements and all participants, as well as the parent/ guardian when required, were asked to sign a consent form.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.
Professor Demosthenes Panagiotakos, co-author of this paper, serves as a Section Editor of the BMRM Journal.

Publisher's Note

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Received: 16 July 2018 Accepted: 27 December 2018
Published online: 20 February 2019

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4. Results

4.1 Dietary Patterns and Lifestyle

Paper 2. Dietary patterns and lifestyle characteristics in adults: results from the Hellenic National Nutrition and Health Survey (HNNHS)

Dietary patterns and lifestyle characteristics in adults: results from the Hellenic National Nutrition and Health Survey (HNNHS)

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Abstract

Objectives: To identify and describe different dietary patterns in a nationally representative sample of Greek adults, and to assess potential associations with lifestyle characteristics.

Study design: Cross-sectional study.

Methods: Dietary patterns were derived by principal component analysis using individual dietary data (24-hour recall) of 3,552 participants of the Hellenic National Nutrition and Health Survey (HNNHS). Analysis of variance and chi-square test were used to determine the lifestyle characteristics of the participants following each pattern.

Results: Three dietary patterns were identified explaining 16.5% of variance; a Traditional pattern, loading positively on olive oil, non-starchy vegetables, and cheese; a Western pattern, loading positively on refined grains, processed meats, and animal fats; and a Prudent pattern, loading positively on fruit, whole grains, and yoghurt, and negatively on fast-food. A fourth, Snack-type pattern, loading positively on sweets, salty snacks and nuts, was identified in women. Primary crude results revealed an association between dietary patterns and socioeconomic status. In multivariate analysis, highest adherence to the Prudent pattern was associated with higher protein and unsaturated fat intake, and lower energy and saturated fat intake (all $P \leq 0.05$); the Western and Traditional patterns were associated with higher energy, and total and saturated fat intake; the Traditional pattern was additionally associated with higher monounsaturated fatty acids intake, whereas the Western pattern with higher alcohol intake (all $P \leq 0.001$).

Conclusions: These findings are valuable for understanding the dietary behaviors of adults in Greece and enabling more focused public health policies for the promotion of healthier food behaviors in the future.

Key words: diet, patterns, food consumption, Mediterranean, national survey, principal component analysis

Introduction

The relationship between diet and health has been strongly established.[1-3] The consumption of foods, such as fruits, vegetables, fish, and whole grains, red meat, and of nutrients, such as saturated fat (SFA) and sodium, have been positively or negatively associated with the risk of various chronic non-communicable diseases, including cardiovascular risk factors and disease,[4-6] obesity,[7] cancer,[8, 9] and depression.[1] The usual approach for exploring these relationships has been to focus on specific foods or nutrients.[10]

Multidimensional approaches, however, such as identification of dietary patterns, have gained considerable interest in nutritional epidemiology in an attempt to account for food-nutrient interactions.[11] The assessment of the cumulative effect of multiple nutrients included in an overall dietary pattern is likely to provide a better explanation of diet-health associations.[11-13] The scientific literature of the past decades has consistently shown the effects of certain diet patterns on health, such as the negative effects of a ''Western type'' and the benefits of the Mediterranean diet on cardiovascular disease (CVD), cancer, longevity, and neurodegenerative diseases.[14-20] From the public health perspective, the description of dietary patterns, which reflect the foods commonly consumed together, can be used to define practical public health policies to promote healthier food behaviors and improve the diet and health of the population.[13] Further understanding of the associations of dietary habits with demographic, lifestyle, and health characteristics is essential for identifying population groups at risk and developing effective public policy strategies.

A standard approach applied for studying national dietary patterns is principal component analysis (PCA), a powerful method for summarizing nutrient and food intake to depict the entire diet.[11] To our knowledge, few studies, in general, and none in Greece have explored the association of dietary patterns and lifestyle characteristics in a nationally representative sample of adults.[21-23] Such analysis is of great value, especially for countries in recession, as economic crises are times of high risk to the physical and mental well-being of the population;[24] people who experience unemployment and impoverishment smoke more, have decreased physical activity, and are at greater risk of alcohol use disorders, than their unaffected counterparts.[24, 25]

The aims of this study were (a) to identify the main dietary patterns in the Greek adult population using individual dietary intake data of the Hellenic National Nutrition and Health Survey (HNNHS), the first nationally representative survey in Greece, (b) to determine the main demographic, lifestyle, sleep, and mental health characteristics of the individuals adhering to the identified patterns, and (c) to assess the nutrient profile of these patterns.

Methods

The survey

HNNHS is the first nutrition and health study in Greece that included a nationally representative sample, irrespective of age and sex.[26] Infants <6 months old, pregnant/lactating women, and people residing outside the country or a private household (e.g., military service, hospitals, institutions) were excluded. The selection of the participants was performed with a random stratified design based on the 2011 census data. Stratification was made according to geographical density criteria by area, and age group and gender distribution. The data collection -realized between September 2013 and May 2015- included an in-person interview at the participant's residence, using the Computer Assisted Personal Interview (CAPI) method, and a health examination appointment in the HNNHS mobile examination units (~1/3 of the participants). Fieldwork was carried out by trained interviewers and health examination was performed by physicians and trained dietitians. All participants (or legal guardian) gave their written informed consent before entering the survey. The study was approved by the Ethics Committee of the Department of Food Science and Human Nutrition of the Agricultural University of Athens and the Hellenic Data Protection Authority (HDPA).

Participants

We used only the adult (≥20 years) HNNHS participants (N=3,703). Of these, 151 (~4%) participants were excluded from the analysis; 45 had missing 24-hour recall (24hR) data, 102 reported extreme energy intake (<600 or >6,000 kcal/d), and 4 were bed bound, hence their diet and lifestyle were expected to deviate from general population. The final study sample consisted of 3,552 participants (41.2% men). Body mass index could not be estimated for 124 participants due to missing weight and/or height data; values were not imputed as the number of missings was small compared to the overall sample size and we did not want to add random misclassification error. Under-reporters (women: 31.9%; men: 32.8%) and over-reporters (3.6%; 3.0%) of energy intake were identified by the modified Goldberg equation,[27, 28] which is based on the energy intake to basal metabolic rate ratio and appropriate by age group cut-off values. Mis-reporters were included in the main analysis, as recommended by the European Food Safety Authority (EFSA),[29] and excluded in sensitivity analyses.

Dietary assessment

Diet intake was assessed by interviewer-administered 24hR recall. The HNNHS 24hR was developed based on the USDA Automated Multiple-Pass Method (AMPM),[30] a method with validated accuracy in estimating energy and nutrient intake. Two 24hR were collected for each participant (15.5% without a second 24hR) on non-consecutive days; one during the interview and one by telephone. Appropriate by age food atlases were the primary tool for portion size estimation, while photographs of standardized household measures (e.g., cups, plates, grids) were also available; during the in-person interview, participants were given copies of these tools to use in the second 24hR. EFSA's FoodEx2 food classification and description system was used for the standardized classification and description of the food items entered in the 24hR.[31] The nutrient content of reported foods was primarily derived from the Nutrition Data System for Research (NDSR; Nutrition

Coordinating Center, University of Minnesota), a food composition database containing over 18,000 foods. Greek food composition tables were additionally used for traditional recipes.

Food items were categorized into 30 food groups based on nutrient composition and culinary use. Mixed dishes (e.g., sandwiches) and recipes (e.g., moussakas) were disaggregated into their ingredients, which were then assigned to the appropriate food group in proportion to their contribution to the recipe. Mixed dishes like pizza, hot dog, burger, and souvlaki, were not disaggregated; they were overall assigned to the fast-food food group, due to their high fat and sodium content and their low nutrient quality.

Demographic, lifestyle, sleep, and depression data

Information on demographics (e.g., sex, age, education, living area), lifestyle, and presence of depression were collected during the interview. Lifestyle indicators included dietary habits (weekly breakfast consumption, meals outside home), physical activity and sedentary activities, smoking status, alcohol consumption, and sleep quality (e.g., night sleep duration and adequacy, afternoon sleep, sleeping disorders). Depression presence was evaluated with the Patient Health Questionnaire (PHQ-9),[32] a self-administered questionnaire for screening, diagnosing, monitoring, and measuring the severity of depression; PHQ-9 is validated for the Greek population.[33] Participants completed PHQ-9 alone; based on their PHQ-9 score (0-27 points), they were classified into five predefined categories of depression symptoms severity (none/minimal, mild, moderate, moderately severe, and severe).

Statistical analysis

Descriptive statistics were calculated for all study variables. Due to the large sample size, all continuous variables were assumed to follow a normal distribution, according to the central limit theorem. To determine reason for stratified analysis, gender mean differences were evaluated using student t-test and chi-square test.

PCA was performed to derive dietary patterns for the overall population and by sex, using intake data (in g/d) for 30 food groups.[34] The Kaiser-Meyer-Olkin (KMO) measure of sample adequacy and the Bartlett test of sphericity were used to assess data adequacy for PCA. The components were evaluated based on how much variance they explained, using eigenvalues (>1.3) and scree plots. Extracted components were rotated with varimax rotation creating orthogonal, uncorrelated components, in order to be more interpretable. For each food group, component loadings (i.e., correlation between the food group and the underlying component) were calculated. For each of the retained components, each survey participants was assigned a score; the score was based on the sum of the component loadings of each food group multiplied with the reported intakes of the specific food group. Dietary patterns were "named" based on the interpretation of the component loadings (i.e., in this analysis, values >0.2 were considered as having an impact in the construction of the component), nutritional knowledge, and traditional Greek cuisine. Analysis of variance (ANOVA) and chi-square test were performed to evaluate mean differences by dietary pattern quintile for continuous and categorical variables, respectively. Distribution of energy and macronutrients (expressed as % of energy, %E) were tested for trend across quintiles using multiple regression analysis, adjusted for age, sex, living area, education, employment status, BMI, and smoking status. Correlations between diet pattern score and energy intakes were tested with Pearson's correlation. All analyses were performed in STATA statistical software (STATA 14.0, StataCorp LP, Texas, USA) with significance level set to 0.05.

Results

Study sample

The mean age of the overall sample was 43.7 (SD: 18.1) years (age range: 20-102 years) **(Table 1)**; no difference was observed between women (44.0 years; SD: 18.0) and men (43.2 years; 18.0). Living area and household size did not differ by sex, whereas the opposite was observed for education and employment status (P<0.001). In particular, the percentage of women vs. men with high education was higher (54.5%, 50.6%), but lower for employment status (44.9%, 57.6%). Significant gender differences were also found for smoking status, mean BMI, and weight status (P<0.001, for all); women vs. men had lower current and former smoker percentage, mean BMI (24.9 kg/m2, 26.4 kg/m2), and overweight/ obesity prevalence (40.1%, 58.4%).

Dietary habits, alcohol consumption, physical activity, sleep quality and presence of depression, also differed by sex (P<0.001, for all). Compared to men, women had more frequently breakfast (5.6 vs. 5.2 d/week), less meals prepared outside home (2.3 vs. 3.4 meals/week), less alcoholic drinks (0.3 vs. 0.6 drinks/d), and increased moderately intense/intense physical activity (75.6 vs. 68.2 min/d); yet, they had more frequently inadequate night sleep (8.1 vs. 7.0 d/month) and higher depression prevalence (16.0 vs. 10.7%).

Table 1. Characteristics of the adult participants of the Hellenic National Nutrition and Health Survey in 2013-2015.

Participant characteritic	Overall	Women	Men	P-value [a]
Sex, n (%)		2,090 (58.8)	1,462 (41.2)	
Age, years	43.7 (18.1)	44.0 (18.0)	43.2 (18.0)	0.184
Age range, years	20-102	20-102	20-92	
Living area, %				
Attica	48.5	48.7	48.3	0.807
Education, % [b]				
Low (≤6 years)	12.0	13.6	9.7	<0.001
Medium (6-12 years)	35.1	31.9	39.6	
High (>12 years)	52.9	54.5	50.6	
Employment status, %				
Employed	50.2	44.9	57.6	<0.001
Unemployed	11.3	12.4	9.8	
Retired	10.5	19.1	22.1	
Student	20.4	10.7	10.1	
Housekeeping	7.6	12.8	0.1	
Marital status, %				
Married	44.6	43.3	46.3	0.075
Household size, n	2.5 (1.3)	2.5 (1.3)	2.5 (1.3)	0.684
Smoking status, %				
Smoker	49.4	31.5	38.3	<0.001
Former smoker	34.3	12.9	21.0	
Never smoked	16.3	55.6	40.6	
BMI				
Mean (SD)[c]	25.5 (4.8)	24.9 (5.2)	26.4 (4.0)	<0.001
Underweight, %	2.7	4.2	0.5	<0.001
Normal, %	49.5	55.6	41.1	
Overweight, %	32.3	25.5	41.6	
Obese, %	15.5	14.6	16.8	

Participant characteritic	Overall	Women	Men	P-value [a]
Dietary habits				
Eating breakfast, d/week	5.5 (2.5)	5.6 (2.3)	5.2 (2.6)	<0.001
Food outside home, meals/week	2.7 (3.1)	2.3 (2.6)	3.4 (3.5)	<0.001
Physical activity [d]				
Moderately intense/Intense, min/d	72.6 (103.3)	75.6 (101.1)	68.2 (106.3)	0.040
Watching TV, h/d	2.0 (1.8)	2.0 (1.8)	2.0 (1.8)	0.433
Using PC/smartphone, h/d [d]	1.9 (2.6)	1.6 (2.4)	2.2 (3.0)	<0.001
Alcohol consumption, drinks/d [e]	0.4 (0.7)	0.3 (0.5)	0.6 (0.8)	<0.001
Sleep quality				
Night sleep duration-weekdays, h/d	7.4 (1.3)	7.5 (1.3)	7.3 (1.3)	<0.001
Night sleep duration-weekend, h/d	7.9 (1.4)	7.9 (1.4)	7.7 (1.4)	<0.001
Sleep during the afternoon, %	43.6	40.2	48.5	<0.001
Inadequate sleep, d/month [e]	7.6 (8.9)	8.1 (9.1)	7.0 (8.5)	<0.001
Depressive disorder (PHQ-9), %	13.8	16.0	10.7	<0.001

BMI, Body Mass Index; PHQ-9, Patient Health Questionnaire-9

Data are presented as mean (SD) for continuous variables and as percentages for categorical variables.

[a] P-values for continuous variables refer to independent samples t-test and for categorical variables to chi-square test ($\chi^{2)}$.

[b] Education was categorized as high if a university/college degree had been completed, as medium if secondary education had been completed, and as low if education for any level below that.

[c] Body Mass Index (BMI) was calculated by dividing self-reported body weight in kilograms (kg) by the squared self-reported height in meters (kg/m^2).

[d] The duration of physical and sedentary activities were based on data refering to the 7 days before the interview.

[e] Values were based on data refering to the 30 days before the interview.

Identification of dietary patterns

Three major dietary patterns were derived for the overall sample, explaining 16.5% of the total variance in the consumption of the 30 food groups **(Table 2)**; in gender stratified analysis, a fourth dietary pattern was revealed only in women. The pattern explaining the highest variance overall (6.1%) and by sex (men: 6.4%; women: 6.1%) was named “Traditional”; it was characterized by significantly positive loadings of traditional Greek foods, such as olive oil, non-starchy vegetables, and cheese. The second pattern was overall characterized by positive loadings for processed meats, animal fats, cheese, and refined grains. This “Western dietary pattern” additionally loaded positively for milk and red meat in men, while negative loadings for legumes and seafood were observed for both men and women. The “Prudent” pattern was similar overall and by sex; it loaded positively for fruits, whole grains, yoghurt, and white meat, and negatively for fast-food. In women, this pattern additionally loaded negatively for sugar sweetened beverages (SSBs), and, in men, for alcohol. A fourth dietary pattern identified in women was named “Snack-type”, as it loaded positively mainly for ready-to-eat foods that require minimum preparation, such as beverages with sweeteners, nuts, sweets, and salty snacks.

In sensitivity analyses, excluding mis-reporters of energy intake did not appreciably change the patterns observed for the first three patterns in women; the Snack-type pattern yielded smaller positive loadings for salty snacks and nuts (<0.10) and greater positive loadings for water and sweeteners (>0.40) (data not shown). In men, none of the patterns notably changed, with the exception of greater negative loadings for fast-food in the Traditional pattern (-0.27), and greater positive loadings for animal fats in the Western pattern (0.56) and milk in the Prudent pattern (0.41).

Table 2. Component loadings for the four major dietary patterns in the Hellenic National Nutrition and Health Survey.

	Overall			Women				Men		
Food groups [a]	Traditional	Western	Prudent	Traditional	Western	Prudent	Snack-type	Traditional	Western	Prudent
Fruits	0.14	-0.10	0.32†	0.15	-0.10	0.33*†	-0.06	0.17	-0.15	0.26†
Fruit juices 100%	0.01	0.14	0.12	0.01	0.10	<0.01	-0.06	<0.01	0.15	0.17
Non-starchy vegetables	**0.56†**	-0.05	0.03	**0.58†**	-0.04	0.04	<0.01	**0.53†**	-0.04	0.02
Starchy vegetables	-0.06	0.04	0.12	-0.04	-0.08	-0.001	-0.03	-0.11	0.05	0.20†
Whole grains	-0.03	0.10	**0.46†**	0.02	-0.02	**0.40†**	0.14	-0.03	0.05	**0.46†**
Refined grains	0.16	0.25†	-0.13	0.08	0.31†	-0.21†	-0.11	0.17	0.26†	-0.02
Legumes	0.18	-0.14	-0.05	0.14	-0.23†	-0.07	0.14	0.24†	-0.13	-0.03
Nuts	0.03	0.12	0.17	0.16	-0.13	0.07	0.35*†	0.04	0.15	0.15
Milk	-0.06	0.11	0.22†	-0.03	0.03	0.12	-0.08	-0.09	0.19	0.28†
Yoghurt	-0.03	-0.08	**0.41†**	-0.04	-0.04	**0.40†**	-0.16	0.02	-0.07	**0.36†**
Cheese	0.33†	0.30†	0.04	0.30†	0.38†	0.04	-0.03	0.33†	0.24†	<0.01
Eggs	0.19	0.19	0.03	0.14	0.18	-0.03	-0.07	0.20†	0.20†	0.06
Seafood	0.06	-0.11	0.05	0.11	-0.20†	0.11	0.13	0.03	-0.11	0.02
Red meat	0.09	0.18	-0.11	0.08	0.22†	-0.14	-0.14	0.01	0.16	-0.04
White meat	-0.15	0.16	0.24†	-0.13	0.06	0.22†	0.07	-0.19	0.15	0.29†
Processed meats	-0.05	**0.38†**	-0.02	-0.07	**0.41†**	<0.01	<0.01	-0.03	**0.35†**	-0.06
Olive oil	**0.60†**	0.02	-0.03	**0.62†**	0.03	-0.03	0.01	**0.55†**	0.02	-0.04
Other vegetable oils	0.07	0.14	-0.01	0.13	-0.07	-0.10	0.30†	0.15	0.18	-0.01
Animal fats	0.00	**0.38†**	0.04	-0.03	**0.41†**	0.01	0.07	0.05	**0.40†**	0.05
Alcohol	0.00	0.16	-0.22†	-0.12	0.11	-0.07	0.20†	0.02	0.10	-0.28†
SSBs	-0.08	0.18	-0.19	0.01	0.04	-0.28†	0.21†	-0.13	0.25†	-0.06
Beverages with sweeteners	-0.14	0.19	0.00	-0.05	0.06	0.04	**0.44†**	-0.09	0.09	-0.10
Salty snacks	-0.08	0.13	-0.02	-0.03	-0.002	-0.03	**0.28†**	-0.07	0.18	-0.04
Sweets	-0.07	0.23†	-0.09	0.04	<0.01	-0.25	0.34†	-0.04	**0.32†**	-0.03
Spices/ Herbs	-0.04	0.18	0.09	-0.01	0.13	0.08	0.11	-0.01	**0.24†**	0.01
Water	0.03	0.27†	0.21†	0.01	0.29†	0.38†	0.12	-0.01	0.15	0.13
Coffee	-0.04	0.19	-0.17	-0.07	0.26†	0.06	0.21†	-0.003	0.14	**-0.33*†**
Tea	-0.04	0.04	0.20†	-0.01	-0.06	0.13	0.16	0.04	0.04	0.19
Sweeteners	-0.06	0.10	0.09	-0.07	0.07	0.19	0.30†	0.02	0.06	0.03
Fast-food	-0.11	0.07	-0.30*†	-0.09	-0.02	-0.26†	0.07	-0.18	0.10	-0.27†
Variability explained, %	6.1	5.9	4.5	6.1	5.7	4.6	4.3	6.4	5.9	4.8

The unique characteristics of each component (dietary pattern) are presented in **bold.** *Marginally unique dietary characteristic for each component. † Loadings ≥0.20 and ≤-0.20.

[a] The definitions of food groups are as follows: *fruits*, total fresh, dried, and canned fruits (g/d); *fruit juices 100%*, total 100% fruit juices (g/d); *non-starchy vegetables*, total fresh and canned vegetables (g/d), excluding starchy vegetables; *starchy vegetables*, total starchy vegetables (e.g., potatoes, corn) (g/d); *whole grains*, total grain foods with ≥1.0 g of fiber per 10 g of carbohydrate (g/d); *refined grains*, total refined grain foods, including rice and oat milk (g/d); *legumes*, total beans, legumes and soy products (g/d); *nuts*, total nuts and seeds, including peanut butter and almond milk (g/d); *milk*, total non-, low-, and full-fat milk (g/d), excluding plant-derived alternatives; *yoghurt*, total non-, low-, and full-fat yoghurt (g/d); *cheese*, total non-, low-, and full-fat cheese (g/d); *eggs*, total eggs (g/d); *seafood*, total fresh, frozen, and processed seafood (g/d); *red meat*, total red unprocessed meats, including offal (g/d); *white meat*, total white

unprocessed meats (g/d); *processed meats*, total processed meat intake (g/d); *olive oil*, total olive oil (g/d); *other vegetable oils*, total vegetable oils other than olive oil (e.g. margarine, sunflower oil) (g/d); *animal fats*, total animal fats (e.g. butter, lard) (g/d); alcohol; total alcohol (g/d); *SSBs (sugar-sweetened beverages)*, total SSBs with added sugar; *beverages with sweeteners*, total beverages wih added sweeteners (e.g., aspartame); *salty snacks*, total salty snacks (e.g., chips, crackers) (g/d); *sweets*, total sweets and confectionary (e.g., chocolate, desserts, cake, croissant, cookies) (g/d); *spices/herbs*, total spices and herbs, including mustard and vinegar (g/d); *water*, total water (g/d); *coffee*, total coffee (g/d); *tea*, total tea (g/d); *sweeteners*, total sweeteners (g/d); *fast-food*, total fast-food, including pizza, burger, hot dog, french fries, souvlaki, and pastries (g/d).

Demographic, lifestyle, and mental health characteristics and dietary patterns

Participants with highest (Q5) vs. lowest (Q1) adherence to the Traditional pattern were more likely to be married and live outside Attica, and less likely to be of high education and employed **(Table 3)**. Interestingly, the Traditional pattern was associated with higher prevalence of overweight (P=0.026) and obesity (P<0.001) but lower prevalence of smoking (P=0.014). These results did not substantially change by sex. In contrast, individuals with highest vs. lowest Western pattern score were more likely to be of younger age, higher education and employed (all P<0.001); women with highest vs. lowest adherence were additionally less physically active (P=0.046), and more likely to be smokers (P<0.001). Both women and men with highest vs. lowest Western pattern adherence, were associated with higher consumption of prepared outside home meals, lower weekly frequency of having breakfast, and higher alcohol consumption. Findings for the Prudent pattern were similar to the Traditional in terms of most participant characteristics; yet, overweight and obesity prevalence did not differ across quintiles neither in women nor men. Highest vs. lowest adherence to the Snack-type pattern yielded similar findings with those in the Western dietary pattern. Remarkably, the Snack-type pattern was associated with lower sleep quality, indicated by higher frequency of inadequate night sleep, as well as with the presence of depression (both P<0.001).

Table 3. Demographic and lifestyle characteristics per quintile of dietary pattern scores overall and by sex.

		Traditional			Western			Prudent			Snack-type		
	N	Q1	Q5	P-value	Q1	Q5	P-value	Q1	Q5	P-value	Q1	Q5	P-value
Overall													
Age, years	3,552	39.3 (17.3)	45.3 (17.6)	0.094	55.1 (19.1)	34.6 (12.5)	<0.001	36.6 (13.6)	46.5 (19.1)	<0.001			
Living in Attica	3,544	54.7	39.9	<0.001	43.3	52.9	0.006	51.1	51.0	0.169			
Education, %	3,543												
Low		8.5	11.6	0.009	27.5	2.1	<0.001	4.8	11.6	<0.001			
High		56.1	49.4	0.030	41.0	59.8	<0.001	57.8	55.3	0.003			
Occupational status, %	3,541												
Employed		53.7	48.9	<0.001	32.8	64.8	<0.001	61.2	46.4	<0.001			
Unemployed [a]		32.2	41.7	0.001	61.2	20.3	<0.001	25.7	44.7	<0.001			
Marital status, %	3,548												
Married		37.0	52.3	<0.001	57.3	31.7	<0.001	36.9	44.3	<0.001			
BMI, kg/m	3,428	25.0 (4.5)	26.2 (4.7)	<0.001	26.1 (5.1)	25.1 (4.6)	<0.001	24.9 (4.6)	25.5 (4.6)	<0.001			
Overweight, %		30.9	34.2	0.026	35.1	30.5	0.249	30.6	34.4	0.553			
Obese, %		11.9	19.2	<0.001	18.7	13.7	0.062	12.3	13.9	0.006			
Dietary habits													
Eating breakfast, d/week	3,539	5.0 (2.7)	5.6 (2.4)	<0.001	5.6 (2.4)	5.1 (2.6)	<0.001	4.4 (2.8)	6.2 (1.9)	<0.001			
Food outside home, meals/week	3,518	3.4 (3.7)	2.4 (2.7)	<0.001	1.5 (2.1)	4.0 (3.6)	<0.001	4.1 (3.6)	2.1 (2.6)	<0.001			
Physical activity [b]													
Moderately intense/Intense, min/d	3,452	66.7 (94.5)	73.6 (104.8)	0.025	75.4 (101.3)	71.0 (107.8)	0.877	64.9 (100.6)	69.5 (92.5)	0.026			
Watching TV, h/d	3,513	2.0 (1.9)	2.1 (1.9)	0.228	2.3 (1.9)	1.7 (1.8)	<0.001	1.9 (1.7)	2.0 (1.9)	0.376			
Using PC/smartphone, h/d [c]	2,948	2.6 (3.0)	2.0 (2.7)	<0.001	1.6 (2.4)	2.7 (3.1)	<0.001	2.6 (3.1)	2.1 (2.7)	<0.001			
Smoking status, %	3,539												
Smoker		38.2	32.9	0.014	23.2	44.7	<0.001	51.7	23.5	<0.001			
Former smoker		13.5	21.3	<0.001	15.4	15.0	0.641	13.0	20.3	<0.001			
Never smoked		48.3	45.8	0.092	61.5	40.3	<0.001	35.4	56.2	<0.001			
Alcohol consumption, drinks/d [d]	3,517	0.4 (0.7)	0.5 (0.7)	0.031	0.2 (0.5)	0.6 (0.8)	<0.001	0.7 (1.0)	0.3 (0.5)	<0.001			
Sleep quality													
Night sleep duration Sun-Thu, h/d	3,440	7.5 (1.4)	7.4 (1.3)	0.348	7.5 (1.3)	7.3 (1.4)	0.198	7.3 (1.5)	7.5 (1.3)	0.116			
Night sleep duration Fri-Sat, h/d	3,434	8.0 (1.5)	7.8 (1.3)	0.009	7.8 (1.3)	7.9 (1.4)	0.029	7.9 (1.4)	7.9 (1.4)	0.818			
Sleep during the afternoon, %	3,527	38.2	48.5	<0.001	47.9	40.1	0.002	39.9	46.0	0.174			
Inadequate sleep, d/month [d]	3,419	8.8 (9.6)	7.1 (8.4)	0.001	6.1 (8.5)	9.2 (9.2)	<0.001	8.8 (9.4)	7.5 (8.9)	<0.001			
Depressive disorder (PHQ-9), %	3,529	17.5	11.6	0.006	11.1	15.7	0.111	14.1	13.7	0.708			
Women													
Age, years	2,090	40.3 (18.1)	45.9 (17.3)	<0.001	51.9 (19.1)	36.4 (14.0)	<0.001	36.7 (15.5)	47.3 (18.4)	<0.001	53.9 (20.0)	36.9 (13.7)	<0.001
Living in Attica	2,084	52.0	41.2	0.012	46.6	53.1	0.322	46.2	50.2	0.477	43.3	50.0	0.004

		Traditional			Western			Prudent			Snack-type		
	N	Q1	Q5	P-value	Q1	Q5	P-value	Q1	Q5	P-value	Q1	Q5	P-value
Education, %	2,085												
Low		10.8	13.0	0.302	24.4	4.8	<0.001	7.9	13.2	0.003	31.7	3.4	<0.001
High		54.8	55.4	0.846	45.0	61.4	<0.001	58.3	56.8	0.219	40.5	66.0	<0.001
Occupational status, %	2,084												
Employed		48.9	45.0	0.370	33.3	56.4	<0.001	51.1	41.5	0.030	35.1	56.4	<0.001
Unemployed [a]		36.7	46.4	0.008	60.3	29.3	<0.001	34.3	49.4	<0.001	59.6	30.7	<0.001
Marital status, %	2,087												
Married		34.6	51.4	<0.001	50.7	34.1	<0.001	35.9	44.6	0.008	49.6	36.4	<0.001
BMI, kg/m	1,994	24.4 (4.8)	25.5 (5.5)	<0.001	25.6 (5.3)	24.4 (5.5)	0.012	24.0 (5.6)	25.6 (5.3)	<0.001	25.5 (4.8)	24.1 (5.5)	<0.001
Overweight, %		23.7	25.2	0.188	32.8	20.3	0.002	20.4	29.0	0.131	32.7	22.3	0.005
Obese, %		12.1	19.2	0.015	15.7	14.6	0.553	10.4	16.9	0.113	16.8	10.9	0.003
Dietary habits													
Eating breakfast, d/week	2,081	5.1 (2.6)	5.9 (2.1)	<0.001	5.9 (2.2)	5.5 (2.4)	0.107	5.0 (2.6)	6.4 (1.6)	<0.001	6.1 (2.0)	5.4 (2.4)	<0.001
Food outside home, meals/week	2,068	2.8 (1.9)	1.9 (2.3)	<0.001	1.3 (1.8)	3.0 (2.9)	<0.001	3.1 (2.9)	1.7 (2.2)	<0.001	1.4 (1.9)	3.0 (2.8)	<0.001
Physical activity [b]													
Moderately intense/Intense, min/d	2,030	65.8 (95.0)	76.1 (97.6)	0.112	89.1 (105.9)	70.0 (107.1)	0.046	63.6 (92.5)	71.7 (90.1)	0.033	75.7 (95.8)	70.2 (97.6)	0.662
Watching TV, h/d	2,063	1.9 (1.9)	2.1 (1.9)	0.140	2.2 (1.8)	1.7 (1.7)	<0.001	2.0 (1.9)	2.1 (1.8)	0.783	2.2 (1.7)	1.7 (1.6)	<0.001
Using PC/smartphone, h/d [c]	1,732	2.2 (2.9)	1.8 (2.5)	0.112	1.4 (2.0)	2.4 (2.8)	<0.001	2.1 (2.5)	1.9 (2.5)	0.077	1.5 (2.3)	2.3 (2.8)	<0.001
Smoking status, %	2,080												
Smoker		38.4	29.0	0.012	21.2	42.8	<0.001	39.1	25.2	0.001	16.6	43.0	<0.001
Former smoker		11.4	17.5	0.018	13.5	12.7	0.338	11.3	16.6	0.086	10.6	16.4	0.195
Never smoked		50.2	53.5	0.107	65.3	44.2	<0.001	49.6	58.2	0.056	72.8	40.6	<0.001
Alcohol consumption, drinks/d [d]	2,067	0.4 (0.6)	0.3 (0.4)	<0.001	0.2 (0.3)	0.4 (0.5)	<0.001	0.4 (0.7)	0.3 (0.4)	<0.001	0.1 (0.4)	0.5 (0.6)	<0.001
Sleep quality													
Night sleep duration Sun-Thu, h/d	2,019	7.6 (1.5)	7.4 (1.2)	0.074	7.6 (1.3)	7.5 (1.3)	0.628	7.6 (1.4)	7.5 (1.3)	0.213	7.7 (1.3)	7.4 (1.3)	0.153
Night sleep duration Fri-Sat, h/d	2,018	8.0 (1.6)	7.8 (1.3)	0.249	8.0 (1.3)	8.0 (1.4)	0.374	8.1 (1.3)	7.9 (1.4)	0.165	7.9 (1.3)	8.0 (1.4)	0.231
Sleep during the afternoon, %	2,074	37.3	42.9	0.141	43.7	37.6	0.041	41.4	42.6	0.372	45.5	35.8	0.007
Inadequate sleep, d/month [d]	2,020	9.0 (9.4)	7.9 (8.8)	0.155	6.6 (8.9)	8.8 (8.9)	0.005	9.0 (9.3)	8.6 (9.6)	0.009	6.4 (8.0)	9.9 (9.7)	<0.001
Depressive disorder (PHQ-9), %	2,074	19.1	12.7	0.081	14.3	16.5	0.466	16.3	15.5	0.803	9.4	20.5	<0.001
Men													
Age, years	1,462	36.4 (15.9)	44.6 (17.6)	<0.001	55.3 (19.4)	33.7 (11.6)	<0.001	37.3 (12.4)	46.4 (20.0)	<0.001			
Living in Attica	1,460	58.4	39.9	<0.001	41.6	49.8	0.095	53.2	51.6	0.103			
Education, %	1,458												
Low		4.8	9.3	0.008	22.6	1.4	<0.001	4.5	7.9	<0.001			
High		52.6	48.6	0.876	42.5	56.2	0.004	55.0	51.0	0.012			
Occupational status, %	1,457												

		Traditional			Western			Prudent			Snack-type		
	N	Q1	Q5	P-value	Q1	Q5	P-value	Q1	Q5	P-value	Q1	Q5	P-value
Employed		61.0	58.6	0.282	41.8	71.8	<0.001	69.2	51.6	<0.001			
Unemployed [a]		21.9	33.5	<0.001	53.8	13.1	<0.001	19.2	39.5	<0.001			
Marital status, %	1,461			<0.001			<0.001			<0.001			
Married		32.4	51.6		64.2	28.2		37.7	44.5				
BMI, kg/m	1,434	25.9 (4.0)	26.6 (4.0)	0.116	26.7 (4.1)	25.9 (4.0)	0.025	25.9 (3.8)	26.0 (3.5)	0.004			
Overweight, %		40.5	42.7	0.866	44.5	39.9	0.565	41.2	42.1	0.251			
Obese, %		12.1	18.2	0.114	18.0	13.5	0.305	15.1	12.8	0.084			
Dietary habits													
Eating breakfast, d/week	1,458	4.8 (2.8)	5.6 (2.4)	0.002	5.3 (2.7)	5.0 (2.7)	0.118	4.0 (2.9)	6.0 (2.2)	<0.001			
Food outside home, meals/week	1,450	4.6 (4.3)	2.7 (2.7)	<0.001	2.0 (2.4)	4.5 (3.7)	<0.001	4.8 (3.9)	2.7 (2.9)	<0.001			
Physical activity [b]													
Moderately intense/Intense, min/d	1,422	65.4 (95.1)	72.4 (113.7)	0.068	62.8 (98.1)	79.0 (118.7)	0.082	78.5 (119.8)	69.7 (106.0)	0.256			
Watching TV, h/d	1,450	2.1 (1.9)	2.0 (1.8)	0.946	2.4 (2.0)	1.7 (1.7)	<0.001	1.8 (1.7)	1.9 (1.8)	0.010			
Using PC/smartphone, h/d [c]	1,212	3.2 (3.2)	2.1 (2.6)	<0.001	2.1 (2.9)	3.0 (3.3)	0.009	2.9 (3.3)	2.6 (3.2)	0.242			
Smoking status, %	1,459												
Smoker		41.6	37.7	0.193	36.1	42.8	0.057	61.3	25.1	<0.001			
Former smoker		17.8	24.0	0.242	24.4	16.1	0.076	13.4	25.4	<0.001			
Never smoked		40.6	38.4	0.366	39.5	41.1	0.787	25.3	49.5	<0.001			
Alcohol consumption, drinks/d [d]	1,450	0.6 (0.8)	0.7 (0.9)	0.204	0.5 (0.9)	0.7 (1.0)	0.006	1.0 (1.2)	0.5 (0.7)	<0.001			
Sleep quality													
Night sleep duration Sun-Thu, h/d	1,421	7.3 (1.4)	7.3 (1.4)	0.949	7.3 (1.4)	7.3 (1.4)	0.868	7.1 (1.4)	7.4 (1.3)	0.025			
Night sleep duration Fri-Sat, h/d	1,416	8.0 (1.4)	7.7 (1.4)	0.032	7.6 (1.4)	7.9 (1.4)	0.079	7.7 (1.4)	7.8 (1.3)	0.447			
Sleep during the afternoon, %	1,453	36.8	51.4	<0.001	59.0	41.2	<0.001	39.3	48.8	0.005			
Inadequate sleep, d/month [d]	1,399	7.7 (9.1)	6.8 (8.5)	0.071	5.6 (8.1)	9.3 (9.2)	<0.001	8.8 (9.6)	6.7 (8.4)	<0.001			
Depressive disorder (PHQ-9), %	1,455	14.4	9.3	0.216	8.0	14.8	0.003	11.4	9.3	0.909			

BMI, Body Mass Index; PHQ-9, Patient Health Questionnaire-9; Q1, quintile 1, including individuals with lowest dietary pattern score; Q5, quintile 5, including individuals with highest dietary pattern score.

Data are presented as mean (SD) for continuous variables and as percentages for categorical variables. P-values for continuous variables refer to analysis of variance (ANOVA) and for categorical variables to chi-square test (χ^2).

[a] Including students and individuals who reported housekeeping as their occupation.

[b] The duration of physical and sedentary activities were based on data refering to the 7 days before the interview.

[c] This question were only made in adults 18-65; the missing values are 19 in women and 9 in men.

[d] The number of days was based on data refering to the 30 days before the interview.

Energy intake and contribution of macronutrients

Total energy was positively correlated with the Western dietary pattern (women: r=0.36, men: r=0.50), and Snack-type pattern (0.43); all other correlations were generally low (<0.20) (data not shown). In energy contribution by macronutrient, moderate correlations were observed only between the Traditional pattern and %E from total fat and MUFA in both women (0.42 and 0.51, respectively) and men (0.33, 0.39), and between the Prudent pattern and %E from total fat and MUFA in the overall population (0.31, 0.40). Adjusted regression analysis showed that high adherence to all dietary patterns was associated with higher energy intake, with the exception of the Prudent pattern that was associated with lower energy intake (P≤0.001) **(Table 4)**. Overall and by sex, high agreement with the Prudent pattern was associated with better diet quality, including higher percentage of energy intake from protein, MUFA, and PUFA, and lower from SFA and alcohol (all P≤0.05). Conversely, high adherence to the Western dietary pattern was associated with higher %E from total fat, SFA, and alcohol (all P≤0.001). The Traditional and Western patterns were also associated with higher %E from total fat; the former, though, was additionally associated with higher %E from MUFA (P≤0.001). The Snack-type pattern was associated only with higher %E from PUFA (P≤0.001).

Table 4. Energy and nutrient intakes per quintiles of dietary pattern scores overall and by sex.

	Traditional		Western		Prudent		Snack-type	
	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5
Overall								
Energy, kcal/d	1839 (941)	2404 (913)***	1301 (565)	2781 (972)***	2416 (991)	1924 (844)***		
Protein, %E	17.7 (7.5)	15.7 (4.4)***	17.2 (6.4)	16.5 (5.1)***	15.6 (5.3)	18.7 (6.5)***		
Carbohydrates, %E	50.8 (15.7)	43.0 (13.0)***	48.6 (14.8)	44.9 (13.7)***	49.6 (15.6)	46.7 (13.8)***		
Total fat, %E	33.8 (10.5)	43.9 (9.8)***	37.2 (10.9)	39.5 (10.6)***	36.1 (10.8)	37.4 (10.2)***		
SFA, %E	11.8 (4.9)	13.5 (4.1)***	11.2 (4.3)	13.4 (4.2)***	12.4 (4.6)	12.0 (4.1)***		
MUFA, %E	14.0 (5.7)	21.3 (6.4)***	18.0 (7.1)	16.9 (6.1)***	15.7 (6.2)	16.6 (5.8)***		
PUFA, %E	5.5 (4.5)	6.0 (2.8)***	5.2 (2.2)	6.3 (3.8)***	5.5 (3.9)	5.9 (3.4)*		
Alcohol, g/d	8.6 (21.9)	8.1 (19.9)***	2.2 (5.9)	15.9 (32.2)***	16.9 (31.4)	4.5 (13.8)***		
Women								
Energy, kcal/d	1617 (786)	2101 (764)***	1463 (694)	2228 (781)***	2164 (884)	1711 (704)***	1420 (597)	2256 (915)***
Protein, %E	17.6 (8.2)	15.7 (4.8)***	16.7 (6.3)	16.8 (4.5)	14.9 (5.8)	19.0 (6.3)***	18.0 (5.4)	14.7 (6.2)***
Carbohydrates, %E	52.4 (16.6)	43.6 (12.8)***	49.5 (14.2)	45.2 (14.2)***	48.7 (13.1)	48.1 (14.4)**	46.0 (13.3)	48.7 (14.0)***
Total fat, %E	32.1 (10.6)	44.3 (8.9)***	37.4 (10.1)	40.2 (10.9)***	38.2 (10.4)	36.3 (10.0)***	38.8 (10.8)	38.2 (11.3)
SFA, %E	11.6 (4.9)	13.5 (4.0)***	10.7 (4.2)	14.2 (4.3)***	12.9 (4.5)	11.9 (4.1)***	13.2 (4.5)	11.8 (4.7)***
MUFA, %E	13.1 (5.5)	21.3 (5.6)***	17.8 (6.4)	17.1 (6.2)***	16.7 (6.1)	16.2 (5.5)***	18.0 (6.6)	16.5 (6.5)***
PUFA, %E	5.3 (5.1)	6.3 (3.0)***	6.1 (3.3)	5.8 (3.1)***	6.0 (4.5)	5.4 (2.8)*	4.6 (2.3)	7.3 (4.7)***
Alcohol, g/d	9.9 (25.2)	3.3 (7.6)***	1.6 (3.9)	8.3 (18.2)***	8.7 (20.7)	3.5 (13.1)***	1.0 (3.9)	11.9 (25.9)***
Men								
Energy, kcal/d	2101 (950)	2706 (979)***	1494 (665)	3200 (956)***	2651 (1044)	2266 (913)***		
Protein, %E	18.7 (6.4)	15.4 (4.5)***	17.4 (6.8)	16.5 (4.7)***	15.7 (4.2)	18.3 (6.4)***		
Carbohydrates, %E	48.2 (14.9)	42.3 (13.4)***	47.0 (15.5)	44.2 (13.3)***	49.5 (16.2)	44.2 (12.3)***		
Total fat, %E	34.4 (9.6)	44.2 (10.8)***	37.2 (11.8)	40.1 (9.9)***	35.0 (10.3)	39.0 (10.3)***		
SFA, %E	11.9 (4.5)	13.5 (4.3)***	11.2 (4.4)	13.6 (4.1)***	12.0 (4.6)	12.3 (3.9)***		
MUFA, %E	14.6 (5.2)	21.5 (7.2)***	18.2 (7.7)	17.2 (5.8)***	15.2 (5.7)	17.7 (6.4)***		
PUFA, %E	5.2 (2.8)	5.9 (2.6)***	5.0 (1.9)	6.4 (3.7)***	5.2 (3.1)	5.9 (2.9)**		
Alcohol, g/d	11.2 (25.7)	12.0 (27.4)	6.3 (13.9)	17.8 (35.0)***	24.8 (37.2)	6.0 (12.8)***		

%E, Percentage of energy intake; Q1, quintile 1, including individuals with lowest dietary pattern score; Q5, quintile 5, including individuals with highest dietary pattern score; SFA, Saturated fatty acids; MUFA, Monounsaturated fatty acids; PUFA, Polyunsaturated fatty acids

Data are presented as mean (SD). P-values refer to regression analysis adjusted for age, sex, living area, education level, employment status, BMI, and smoking status. Sex was not a covariate in the stratified by sex analysis.

*P<0.05, **P≤0.01, ***P≤0.001

Discussion

This is the first analysis to explore the dietary patterns in a nationally representative sample of adults in Greece. Using PCA, three main dietary patterns -Traditional, Western, and Prudent- were derived overall and by sex, with distinct food consumption behaviors, as well as demographic, lifestyle, and mental health determinants; a fourth Snack-type pattern was identified in women.

In this analysis, we identified both patterns that are consistently reported in the literature; the healthy "Prudent" pattern and the unhealthy Western pattern.[11, 16, 17, 22, 35] Yet, the pattern that explained the greatest part of the total variance was the Traditional pattern. This pattern was considered as a proxy Mediterranean dietary pattern because, although it effectively had high loadings for fundamental components of the Mediterranean diet,[36-38] such as non-starchy vegetables and olive oil, it had weak loadings for others, such as whole grains, fish, and legumes. On the contrary, it had high loadings for core foods of the Greek cuisine, such as cheese. In men, the Traditional pattern, further loaded positively for eggs and negatively for white meat, characteristics that relate more to the Western dietary pattern. The dietary behaviors of this in-between dietary pattern led to both healthier dietary intakes, with high %E from unsaturated fats, and less healthy ones, with high caloric and SFA intake. Our findings are in line with previous findings showing that the Mediterranean diet, in its original definition, is being progressively westernized, leading to a nutrition transition reflected by a shift towards high-saturated, high-sugar, refined and processed foods.[39] These findings suggest a westernization of the Mediterranean diet, as this is described in the literature, and are consistent with compiling evidence suggesting that the Mediterranean diet is now progressively disappearing in the Mediterranean countries.[39-42]

The Western pattern identified in this analysis is in line with similar patterns identified across literature, which are characterized by positive loadings for red and/or processed meat, refined grains, desserts, SSBs, and high-fat products. In Greece, previous studies in the general population have revealed a Western-type pattern, although this also included healthier dietary behaviors, such as high fruit and vegetable intakes,[43] or was vaguely described, based mainly in its association with increased cardiovascular disease risk.[44] Highest vs. lowest adherence to the Western pattern was linked to higher intakes of energy, SFA, and alcohol and lower intake of carbohydrates, consistent with the high meat, egg, and dairy content of this pattern.

The fourth dietary pattern, which was identified only in women, was described by ready-to-eat and easy-to-prepare foods. Notably, although the Snack-type pattern had positive loadings for salty snacks, sweets, and nuts, there was a tendency for counterbalancing the high-caloric content of such foods with increased sweetener intake. Few studies have previously identified a group of consumers characterized by high consumption of foods commonly classified as snacks, such as chips, crackers, beverages, desserts, and confectionary.[22, 45] The identification of such a pattern in this analysis could be partially explained by the level of aggregation of chosen foods, which identified groups of snacks (e.g., salty, sweets) separately.

The description of dietary patterns by demographic and lifestyle characteristics, showed both consistent and contradictory to the existing literature findings. In line with previous findings, individuals adherent to the healthier patterns (i.e., Traditional and Prudent) had better dietary habits in terms of breakfast consumption frequency and eating food prepared outside home, they were less likely to smoke and more likely to exercise. This analysis also showed that the socio-economic status had a strong influence on food consumption. However, the direction of the results contradicted previous findings; the Western and Snack-type patterns were associated with positive employment status and high education level, whereas the opposite was observed for the Traditional and Prudent patterns. Existing evidence shows that higher socio-economic and educational status is associated with healthier food consumption, such as fruit, vegetables, and whole grains, and lower socio-economic and educational status is associated with processed and unprocessed meats and energy-dense food consumption, such as fast-food and sweets.[21-23, 46, 47] These contradictory findings are complemented by the BMI results, with higher prevalence of overweight and obesity being reported for the Traditional and lower for the Western and Snack-type ones. A potential explanation for these findings is the overall profile of the individuals adhering to each pattern. Women and men adhering to the Western pattern are considerably younger, and in their productive age, hence, their energy requirements would be expected to be higher compared to older and/or potentially unemployed adults; therefore, the caloric intake, despite high for this pattern, might still counterbalance energy needs. Moreover, these results refer to a period of national economic crisis; recession periods have been associated with lower diet quality, deterioration of dietary habits, and lower adherence to the Mediterranean diet.[48, 49] Adherent to the Traditional pattern individuals were more likely to reside outside the urban Attica area, potentially with higher access to agricultural products from own or close environment production; therefore, olive oil and vegetables could have been obtained at no or low cost, while other healthy foods, such as seafood and whole grains that are more expensive were not consumed in high amounts. However, since there are no available nationally representative data in Greece referring to a time point before the recession, no safe assumptions can be made.

An interesting finding of this analysis was the significant associations of sleep quality and depression with dietary patterns. In particular, we found that the Traditional and Prudent patterns were associated with lower sleep disorders prevalence; this is in line with limited existing evidence, which suggests, however, that healthy patterns are associated with higher sleep quality and lower prevalence of sleep disorders.[50] Remarkably, although sleep disorders are known to increase with age,[51] individuals that were highly adherent to the Traditional and Prudent patterns were older that those that closely adhered to the Western and Snack-type patterns. The suggested mechanisms underlying this finding include mainly tryptophan, a precursor to sleep-promoting hormones; higher in protein dietary patterns, provide greater amounts of tryptophan, potentially leading to better sleep quality. In terms of depression, we found positive associations for Snack-type pattern in women and Western pattern in men. Currently, the evidence on the association of Western-type patterns and the likelihood of depression is conflicting, with studies reporting either a positive or no association, mainly due to differences in study characteristics and methodological limitations.[52, 53] Overall, this analysis suggests that an association between sleep quality, mental health, and dietary patterns may exist, which warrants further research.

Our study had several strengths. This is the first analysis to derive dietary patterns, using PCA, in a nationally representative sample of Greek adults with broad age range.[43, 44, 54, 55] The data collection period covered over 1.5 year, taking into account the seasonal consumption of certain foods, and capturing the exposure to foods consumed during certain periods (e.g., holidays). The source of dietary data was multiple 24hR, rather than food frequency questionnaires that are commonly used for the identification of dietary patterns.[17, 18, 56] Although 3-7 days food records are considered as the gold standard, we used the AMPM to administer our 24hR, a method that maximizes the reported food consumption accuracy and standardizes the reported foods description. Different levels of food aggregation were used, leading to the identification and description of the previously confounded Snack-type pattern. The dietary patterns were derived by PCA, a data-driven method used to investigate dietary patterns in various populations globally.[21, 57-59] A wide range of demographic, and lifestyle variables were included to describe the derived dietary patterns.

Limitations should also be considered. PCA, although a data-driven method with reasonable reproducibility and validity,[58, 60] involves subjective decision-making in some steps of the analytical process. The identified dietary patterns explained a low percentage (4.3%-6.4%) of the total variance in dietary intake, which is, nonetheless, similar with the findings of other studies.[21, 22, 50, 57, 61] The amount of explained variance largely depends on the number of food groups included in the PCA, and it decreases with greater numbers of food groups;[62] yet our findings from the analysis of 30 food groups were still similar to others of 20 food groups.[57] Moreover, we had a large percentage of energy intake mis-reporters, consistent with what has been previously reported; after excluding them, in sensitivity analyses, the derived patterns remained generally the same.

In conclusion, three main dietary patterns were identified among Greek adults with distinct demographic, lifestyle, and mental health characteristics. These findings provide new insights on the diverse food consumption behaviors among Greek adults, and a picture of the dietary intake patterns in a period of a national economic crisis. In terms of public health, our findings are critical for achieving a wide range of policy and research objectives, including surveillance, planning, evaluation, national monitoring, and public interventions. The patterns derived from this study can be further used for exploring their association with health outcomes, such as chronic diseases.

Acknowledgements

We thank all field workers (in alphabetical order based on surname):

Ioanna Adami, Aggeliki Anastasiou, Elisavet Anestiadou, Nikolaos Altanis, Georgios Argyropoulos, Euaggelia Arvanitidou, Anastasios Barounis, Alexandra Basdeki, Polychronis Bazakidis, Dimitra Borsa, Vasileia Chatzistergiou, Theodoros Chrysanidis, Konstantinos Daskalou, Chrysaugi Galanaki, Chrysanthi Gerasimatou, Arriana Gkouvi, Lampros Grampsas, Eleni Ioannidi, Vasiliki Kanaki, Eustratios Karagiannidis, Eirini Kasapidou, Vasiliki Katseni, Georgios Koktsidis, Eirini Konstantakou, Andronikos Kostakidis, Sotiria Kottara, Eleutheria Kourliti, Maria Kourtidou, Aikaterini Lymperopoulou, Nikoleta Markoglou, Aikaterini Markou, Anna Mauromanoli, Panagiota Merou, Areti Miha, Marianna Moira, Ioannis Moschakis, Dimitra Mougopetrou, Konstantina Mouliou, Andromachi Mourtzouhou, Vasiliki Moustakaki, Vissarios Moutsanas, Maria-Aggeliki Mpoulet, Evangelia Nanou, Ioannis Nikolaidis, Giannos-Aggelos Nikolaou, Sakellarios Panagiotakis, Eirini Panagiotou, Panagiotis Papadopoulos, Vasiliki Papageorgiou, Nikolaos Papaspanos, Olga Papazisi, Euthymia-Iro Pappa, Eufrosyni Patiraki, Konstantinos Petsanis, Maria-Christina Polychronopoulou, Nikolitsa Psylia, Alexandros Sachinidis, Avraam Sarafopoulos, Paraskevi Seferidi, Christos Sifnaios, Dimitra Stauropoulou, Myrto Stavrou, Chrysanthi Tatsi, Nena Theodoridou, Anna Theou, Christina-Yakinthi Tzotziou, Georgios Vergos, Agapi Vlachou, Anastasia Xatziapostolou, Iliana Xatzifragou, Adela Zana.

Financial Support

The study was co-funded by Greece and the European Union (European Social Fund) under the Operational Program “Human Resources Development 2007-2013”.

Conflict of interest

None.

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4.2 Dietary Patterns and Cardiovascular Disease

Paper 3. Association between dietary patterns and cardiovascular disease in Greek adults: the Hellenic National Nutrition and Health Survey

Association between dietary patterns and cardiovascular disease in Greek adults: the Hellenic National Nutrition and Health Survey

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Abstract

Background and Aims: Empirically-derived dietary patterns have been shown to have both positive and adverse associations with cardiovascular disease (CVD). Yet, such associations remain unclear in the Greek population with CVD. The aim of this study was to investigate the association between empirically-derived dietary patterns and the presence of CVD and CVD-related medical conditions in a nationally representative sample of Greek adults.

Methods and Results: Adult participants (≥20 years old) of the Hellenic National Nutrition and Health Survey (HNNHS) were included (N=3,552; 41.2% men; 43.7 years, SD: 18.1). Dietary patterns were derived by principal component analysis using 24-hour recall data. The presence of CVD and CVD-related medical conditions, including dyslipidemia (elevated cholesterol and/or triglycerides) and hypertension, was self-reported and defined according to the International Clinical Diagnosis (ICD)-10 codes. Odds ratios of CVD outcomes were estimated across dietary patterns using multivariable logistic regression analysis. Three dietary patterns -Traditional (proxy Mediterranean), Western, and Prudent- were identified explaining 16.5% of the total variance in consumption. Logistic regression analysis, adjusted for CVD risk factors, showed an inverse association between the Traditional dietary pattern and total CVD (OR: 0.53; 95% CI: 0.29-0.97), and a positive association between the Western pattern and dyslipidemia (1.52; 1.02-2.26). The *P*rudent pattern was not significantly associated neither with total CVD outcome nor dyslipidemia.

Conclusion: Multivariable logistic regression revealed that there are significant associations between empirically-derived dietary patterns and CVD prevalence among the Greek adult population.

Key words: dietary pattern, food consumption, national survey, cardiovascular disease, risk factor

Introduction

Cardiovascular disease (CVD) is currently the leading cause of morbidity and mortality worldwide.[1,2] Despite the decreasing trend in CVD related mortality, CVD remains responsible for approximately half of all deaths in most European countries.[3] Multiple risk factors for CVD, such as obesity, hypertension and dyslipidemia, are well established.[4] Suboptimal diet is the leading modifiable risk factor for CVD development and a major contributor to the increased severity of CVD related burdens.[5,6] The diet-related CVD risk is mainly linked to specific foods, rather than nutrients.[5-7] Foods commonly consumed together are reflected in dietary patterns, which in the recent decades have been linked to several health outcomes, mainly CVD, cancer, and diabetes mellitus.[8-13] A better understanding of such dietary patterns is crucial for planning and implementing strategies to reduce diet-related diseases, whereas additionally, food-based guidance is a useful approach for the promotion of healthy dietary patterns in the population.[14]

Dietary patterns are defined either *a priori*, by using current nutrition knowledge and constructing patterns that reflect hypothesis-oriented combinations of foods and nutrients, or *a posteriori*, by applying exploratory statistical methods on observed dietary data to identify potential underlying patterns.[15] A key advantage of the *a posteriori* approach is that, by using the actual dietary data of the population, it takes into account many aspects of the diet rather than focusing on a few hypothesized key food groups. Moreover, food groups used in most *a priori* scores are usually broadly defined, hence not accounting for differences in micronutrients of individual food items (e.g., all vegetables compared with green leafy vegetables, red or dark-yellow vegetables). Several prospective cohort studies have evaluated the benefits of *a priori* defined Mediterranean diet pattern, and have consistently shown that higher adherence is positively associated with lower CVD risk and longevity.[16,17] There seems to be a growing interest, however, in assessing the diet-disease relationship using the *a posteriori* approach.[8,10,13,18,19] For CVD, in particular, there is a considerable number of studies, including randomized controlled trials (RCTs), that have investigated the relationship of *a posteriori* dietary patterns and CVD, with quite contradictory findings.*8,9* Notably, there is limited evidence on empirically-derived patterns and CVD in Southern-European populations, particularly Greece.

In this study, we evaluated the association between *a posteriori* dietary patterns and prevalence of CVD and CVD-related medical conditions, including dyslipidemia, defined as presence of high cholesterol and/or triglycerides, and hypertension, in a nationally representative sample of Greek adults using data from the Hellenic National Nutrition and Health Survey (HNNHS).

Methods

Study population

HNNHS is the first nutrition and health survey in Greece, which included a nationally representative, both for age and sex, sample. The detailed description of the study design, selection of participants, and survey administration has been reported.[20,21] In brief, the total sample of HNNHS consisted of men and women aged ≥6 months that resided in Greece; pregnant and/or breastfeeding women, and people residing outside a private household (e.g., military service, hospitals, institutions) were excluded. The selection of the participants was performed with a random stratified design based on the 2011 census data. Stratification was made according to geographical density criteria by area, and age group and gender distribution. Data were collected between September 2013 and May 2015. Data collection included an in-person interview using the Computer Assisted Personal Interview (CAPI) method, which was administered by trained interviewers at the participant's house, and a health examination in the HNNHS mobile units, performed by medical doctors and trained dietitians. All participants (or legal guardian) gave their written informed consent before entering the survey. The study was approved by the Ethics Committee of the Department of Food Science and Human Nutrition of the Agricultural University of Athens and the Hellenic Data Protection Authority.

This analysis included only the adult participants (≥20 years) of HNNHS (n=3,703); individuals with missing 24-hour recall (24hR) data (n=45), extreme energy intakes (<600 or >6,000 kcal/d; n=102), and those reporting to be bed bound (n=4) were excluded. The final study population consisted of 3,552 participants (41.2% men) with mean age 43.7 (SD: 18.1) years. Mis-reporters, including under- and over-reporters, of energy intake (35.6%), identified by the modified Goldberg equation,[22,23] were included in the main analysis, in accordance with the recommendations of the European Food Safety Authority (EFSA).[24]

Dietary assessment

The assessment of dietary intake was performed by interviewer-administered 24hR. In the HNNHS, the 24hR was developed based on the USDA Automated Multiple-Pass Method (AMPM).[25] The FoodEx2 food classification and description system developed by EFSA[26] was used for the standardized description of the reported food items. Portion size was estimated primarily by appropriate by age food atlases, and secondarily by standardized household measures (e.g., glasses, plates, grids). Two 24hR, one in-person and one by telephone, were collected for each participant (15.5% of the adult participants did not complete a second 24hR). The Nutrition Data System for Research (NDSR; Nutrition Coordinating Center, University of Minnesota) was the primary food composition database, further complemented by Greek food composition tables for traditional recipes. Additional details on the development and administration of the 24hR used in the HNNHS can be found elsewhere.[20,21] Food items were categorized into 30 food groups based on nutrient composition and culinary use. Mixed dishes (e.g., sandwich, salad) and recipes (e.g., lasagna, moussakas) were disaggregated into their ingredients, which were then proportionally assigned to the appropriate food groups; no disaggregation was performed for pizza, hot dog, burger, and souvlaki, which were categorized as fast-food, based on their high fat and sodium content, and their low nutrient quality. Intake for all foods and beverages was expressed in g/d.

The dietary patterns used in this analysis have been previously identified.[20] Briefly, principal component analysis (PCA) was performed to derive patterns overall and by sex. PCA outputs were evaluated based on eigenvalues, scree plots, and interpretation of retrieved components; the identified components were rotated with varimax rotation creating orthogonal, uncorrelated factors.

Three major dietary patterns were identified and accounted for 16.5% of the total variance in consumption: a Traditional, a Western, and a Prudent dietary pattern. A fourth pattern, namely Snack-type, was identified only in women. For the purposes of this analysis, only the 3 patterns identified for the overall population were assessed.

Cardiovascular disease and related conditions assessment

The presence of CVD and diabetes mellitus (DM, as a risk factor for CVD) was determined through the evaluation of each participant's medical history by experienced clinicians and according to the International Classification of Diseases (ICD)-10th version.[27] The outcomes of interest included dyslipidemia (ICD-10 code: E78.0-E78.5), which was defined as total triglyceride level above 150 mg/dl and/or total cholesterol level above 200 mg/dl, or use of prescribed lipid-lowering medication; hypertension (I10), which was defined as average systolic/diastolic blood pressure greater or equal to 140/90 mmHg, or use of prescribed antihypertensive medication; coronary heart disease (CHD; I20-I25); and total cardiovascular disease (CVD; I60-I67, I69.0-I69.4), which included CHD and stroke. DM was defined as fasting blood glucose level above 125 mg/dl, or use of prescribed diabetic medication. Prior to data analysis, the collected medical history information was cross-checked against medication use data, to identify treatment for CVD, dyslipidemia, hypertension, and DM, and avoid misclassification of false negatives.

Demographic and lifestyle data

Demographic characteristics, collected during the CAPI interview, included sex, age, education, and living area; there was a high percentage (17%) of missing data for household income, thus this variable was not assessed. Lifestyle indicators included physical activity (time spent on intense/moderately intense activities), smoking (currently, formerly, never smoked), alcohol consumption (number of drinks consumed per day). The presence of diabetes mellitus (DM) was self-reported. Body Mass Index (BMI) was calculated in kg/m2 from self-reported body weight and height in meters.

Statistical analysis

Descriptive statistics, including frequencies (N %), and means with standard deviations (SD) were calculated for the characteristics of the participants, for categorical and continuous data, respectively. Sex mean differences were tested using student t-test for continuous variables, and chi-square test for categorical data, in order to determine whether stratified analysis was required. Participants were divided into quintiles according to their PCA score (adherence) for each dietary pattern. Food and nutrient intakes are presented as the mean (±standard deviation, SD). Trend association was assessed by assigning ordinal numbers to each quintile of each dietary pattern score and was tested using logistic regression analysis; diet factors were log-transformed if they did not follow a normal distribution.

Logistic regression analysis was performed to calculate the odds ratio (OR) and 95% confidence interval (CI) for the presence of dyslipidemia, hypertension, CHD, and CVD, across quintiles of dietary pattern scores; the lowest quintile was used as the reference category. Three multivariable-adjusted models were fitted by adjusting for potential risk factors of the aforementioned outcomes; (i) age (continuous) and sex, (ii) age, sex, and energy intake (kcal/d), and (iii) age, sex, physical activity (moderately intense or intense, min/d), energy intake, level of education (≤6, 7-12, and >12 years of education), percent of energy intake (%E) from saturated fat (SFA), presence of diabetes, smoking status (current smoker, former smoker, never smoked), alcohol consumption (drinks per day), and Body Mass Index (BMI, kg/m2). All analyses were performed in STATA statistical software (STATA 14.0, StataCorp LP, Texas, USA) with significance level set to 0.05.

Results

The mean (±SD) age of the overall population was 43.7 (SD: 18.1) years (**Table 1**). The prevalence of dyslipidemia and hypertension was 21.5% and 16.6%, with no significant sex differences. In contrast, the prevalence of CHD and total CVD was twice as high for men compared to women (5.3% vs. 1.8% and 6.6% vs. 3.2%, respectively; P<0.001). In terms of demographics, living area did not differ by sex, whereas a higher percentage of women had high education (54.5% vs. 50.6%, P<0.001). In lifestyle factors, a higher percentage of men were current smokers compared to women (38.3% vs. 31.5%, P<0.001); women consumed less alcohol than men (0.3 vs. 0.6 drinks/d) and had higher physical activity (75.6 vs. 68.2 min/d). The presence of DM did not different between men and women, unlike BMI which was higher in men (26.4 kg/m^2 vs. 24.9 kg/m^2, P<0.001).

Table 1. Characteristics of the adult participants of the Hellenic National Nutrition and Health Survey overall and by sex.

	Overall	Women	Men	P-value[1]
Sex, n (%)		2,090 (58.8)	1,462 (41.2)	
Age, years*	43.7 (18.1)	44.0 (18.0)	43.2 (18.0)	0.184
Living area, %				
Attica	48.5	48.7	48.3	0.807
Rest of Greece	51.5	51.2	51.7	
Education, %[2]				
Low (≤6 years)	12.0	13.6	9.7	<0.001
Medium (6-12 years)	35.1	31.9	39.6	
High (>12 years)	52.9	54.5	50.6	
Current smoker, %	34.3	31.5	38.3	<0.001
Alcohol consumption, drinks/d[3]	0.4 (0.7)	0.3 (0.5)	0.6 (0.8)	<0.001
BMI				
Mean (SD)	25.5 (4.8)	24.9 (5.2)	26.4 (4.0)	<0.001
Overweight, %	32.3	25.5	41.6	
Obese, %	15.5	14.6	16.8	
Moderately intense/Intense physical activity, min/d[4]	72.6 (103.3)	75.6 (101.1)	68.2 (106.3)	0.040
Diabetes mellitus, %	4.3	3.9	4.9	0.163
Dyslipidemia, %[5]	21.5	21.5	21.5	0.997
Hypertension, %	16.6	16.7	16.5	0.394
CHD, %[6]	3.3	1.8	5.3	<0.001
Total CVD, %[7]	4.6	3.2	6.6	<0.001

Data are presented as mean (SD) for continuous variables and as percentages for categorical variables.

[1] P-values for continuous variables refer to independent samples t-test and for categorical variables to chi-square test (χ^{2}).

[2] Education was categorized as high if a university/college degree had been completed, as medium if secondary education had been completed, and as low if education for any level below that.
[3] Values were based on data refering to alcohol consumption during the 30 days before the interview.
[4] The duration of physical and sedentary activities were based on data refering to the 7 days before the interview.
[5] Dyslipidemia refers to elevated cholesterol and/or triglyceride levels.
[6] Coronary heart disease (CHD) includes individuals with coronary artery disease, angina, or having undergone myocardial infarction.
[7] Total CVD includes individuals with CHD, stroke, or heart failure.

Dietary patterns and dietary intake

The component loadings of the 3 major dietary patterns identified by PCA are presented in **Table 2**. In brief, the Traditional dietary pattern, which was considered a proxy Mediterranean pattern and explained the highest variance overall (6.1%) and by sex,[20] was characterized by high loadings of olive oil (0.60), non-starchy vegetables (0.56), and cheese (0.33); the Western pattern loaded positively for processed meats (0.38), animal fats (0.38), cheese (0.30), and refined grains (0.27); and the Prudent dietary pattern had positive loadings for whole grains (0.46), yoghurt (0.41), fruits (0.32), and white meat (0.24), and negative for fast-food (-0.30) and alcohol (-0.22). The description of the dietary patterns by sex and their association with sociodemographic and lifestyle factors are reported elsewhere.[20]

Table 2. Component loadings (rotated) for the three major dietary patterns in the Hellenic National Nutrition and Health Survey.

Food groups[1]	Traditional	Western	Prudent
Fruits	+ [b]	- [b]	0.32
Fruit juices 100%	+ [a]	+ [b]	+ [b]
Non-starchy vegetables	0.56	- [a]	+ [a]
Starchy vegetables	- [a]	+ [a]	+ [b]
Whole grains	- [a]	+ [b]	0.46
Refined grains	+ [b]	0.25	- [b]
Legumes	+ [b]	- [b]	- [a]
Nuts	+ [a]	+ [b]	+ [b]
Milk	- [a]	+ [b]	0.22
Yoghurt	- [a]	- [a]	0.41
Cheese	0.33	0.30	+ [a]
Eggs	+ [b]	+ [b]	+ [a]
Seafood	+ [a]	- [b]	+ [a]
Red meat	+ [a]	+ [b]	- [b]
White meat	- [b]	+ [b]	0.24
Processed meats	- [a]	0.38	- [a]

Olive oil	0.60	+[a]	-[a]
Other vegetable oils	+[a]	+[b]	-[a]
Animal fats	+[a]	0.38	+[a]
Alcohol	+[a]	+[b]	-0.22
SSBs	-[a]	+[b]	-[b]
Beverages with sweeteners	-[b]	+[b]	+[a]
Salty snacks	-[a]	+[b]	-[a]
Sweets	-[a]	0.23	-[a]
Spices/ Herbs	-[a]	+[b]	+[a]
Water	+[a]	0.27	0.21
Coffee	-[a]	+[b]	-[b]
Tea	-[a]	+[a]	0.20
Sweeteners	-[a]	+[b]	+[a]
Fast-food	-[b]	+[a]	-0.30
Proportion of variability explained	6.1	5.9	4.5

Absolute values <0.20 are not listed. [a] |Loadings| <0.10. [b] |Loadings| ≥0.10 and <0.20.

[1] The definitions of food groups are as follows: *fruits*, total fresh, dried, and canned fruits (g/d); *fruit juices 100%*, total 100% fruit juices (g/d); *non-starchy vegetables*, total fresh and canned vegetables (g/d), excluding starchy vegetables; *starchy vegetables*, total starchy vegetables (e.g., potatoes, corn) (g/d); *whole grains*, total grain foods with ≥1.0 g of fiber per 10 g of carbohydrate (g/d); *refined grains*, total refined grain foods, including rice and oat milk (g/d); *legumes*, total beans, legumes and soy products (g/d); *nuts*, total nuts and seeds, including peanut butter and almond milk (g/d); *milk*, total non-, low-, and full-fat milk (g/d), excluding plant-derived alternatives; *yoghurt*, total non-, low-, and full-fat yoghurt (g/d); *cheese*, total non-, low-, and full-fat cheese (g/d); *eggs*, total eggs (g/d); *seafood*, total fresh, frozen, and processed seafood (g/d); *red meat*, total red unprocessed meats, including offal (g/d); *white meat*, total white unprocessed meats (g/d); *processed meats*, total processed meat intake (g/d); *olive oil*, total olive oil (g/d); *other vegetable oils*, total vegetable oils other than olive oil (e.g. margarine, sunflower oil) (g/d); *animal fats*, total animal fats (e.g. butter, lard) (g/d); *alcohol*; total alcohol (g/d); *SSBs (sugar-sweetened beverages)*, total SSBs with added sugar; *beverages with sweeteners*, total beverages with added sweeteners (e.g., aspartame); *salty snacks*, total salty snacks (e.g., chips, crackers) (g/d); *sweets*, total sweets and confectionary (e.g., chocolate, desserts, cake, croissant, cookies) (g/d); *spices/herbs*, total spices and herbs, including mustard and vinegar (g/d); *water*, total water (g/d); *coffee*, total coffee (g/d); *tea*, total tea (g/d); *sweeteners*, total sweeteners (g/d); *fast-food*, total fast-food, including pizza, burger, hot dog, french fries, souvlaki, and pastries (g/d).

Food, energy, and macronutrient intake of the participants by quintiles of dietary pattern adherence are shown in **Tables 3-5**. In the Traditional pattern, all dietary factors differed significantly across quintiles (P<0.01), while linear trend was observed for most of them (**Table 3**). Compared to lowest adherence (Q1), participants with highest adherence (Q5) to the Traditional pattern were more likely to consume higher amounts of fruit (183.5 g/d vs. 79.3 g/d), non-starchy vegetables (330.6 g/d vs. 45.7 g/d), olive oil (45.0 g/d vs. 4.4 g/d), and seafood (29.5 g/d vs. 13.0 g/d), but also of cheese (67.4 g/d vs. 17.7 g/d) and red meat (54.9 g/d vs. 28.4 g/d); an inverse trend in the consumed amounts for highest vs. lowest adherence was observed for snacks and beverages, such as sweet snacks (49.0 g/d vs. 68.2 g/d) and sugar-sweetened beverages (SSBs) (92.3 g/d vs. 104.1 g/d). In terms of energy and macronutrients, caloric and total fat intake were higher in highly vs. poorly adherent participants (~2,400 kcal/d vs. ~1,800 kcal/d and ~44%E vs. ~34%E, respectively); consistently with the reported high olive oil intake, the main contributor of higher fat intake was MUFA (21%E vs. 14%E).

All dietary variables, but milk, differed significantly across quintiles of Western pattern adherence (P<0.05), and linear trend was observed for approximately 60% of them (**Table 4**). In foods, participants with highest vs. lowest adherence to the Western pattern were more likely to consume higher amounts of SSBs (179.7 g/d vs. 24.9 g/d), refined grains (195.3 g/d vs. 75.3 g/d), processed meats (37.8 g/d vs. 2.4 g/d), and fast-food (88.0 g/d vs. 35.9 g/d). Conversely, the Western pattern was associated with lower intakes of fruit (94.4 g/d vs. 188.7 g/d), legumes (9.3 g/d vs. 28.7 g/d), and seafood (13.9 g/d vs. 42.8 g/d). Participants in the highest vs. lowest quintile were associated with substantially higher energy intake (2,780 kcal/d vs. 1,300 kcal/d), higher total fat intake by ~2%E, but also higher polyunsaturated fat (PUFA) intake by ~1%E; an inverse association was found for carbohydrates (~45%E vs. ~49%E) and dietary fiber (~13 g/1000kcal vs. ~16 g/1000kcal).

In the Prudent pattern, a linear trend was reported for 14 out of 33 dietary factors (**Table 5**). Participants highly adhering to this healthier pattern were more likely to consume higher amounts of fruits (243.8 g/d vs. 42.3 g/d), whole grains (62 g/d vs. 3.0 g/d), seafood (30.2 g/d vs. 11.0 g/d), and water (~1.5 kg/d vs. ~1.0 kg/d) compared to participants in Q1. Inverse associations were observed for fast-food (18.3 g/d vs. 165.8 g/d) and processed meat (11.9 g/d vs. 21.1 g/d) intake. In terms of energy and macronutrients, participants in the Q5 vs. Q1 were associated with lower energy intake (~1,900 kcal/d vs. ~2,400 kcal/d), and higher %E intake from protein (18.7%E vs. 15.6%E).

Table 3. Food, energy, and macronutrient intake across quintiles of adherence to the Traditional dietary pattern.

	Q1 (n=711)	Q2 (n=710)	Q3 (n=711)	Q4 (n=710)	Q5 (n=710)	P
Foods						
Fruits, g/d	79.3 (111.1)	108.1 (134.7)	123.0 (142.2)	148.4 (180.3)	183.5 (270.8)	<0.001*
Non-starchy vegetables, g/d	45.7 (49.0)	80.1 (58.0)	128.5 (75.7)	183.8 (89.5)	330.6 (220.7)	<0.001*
Starchy vegetables, g/d	44.6 (126.4)	31.4 (70.8)	29.0 (58.6)	34.5 (81.3)	26.1 (69.4)	<0.001*
Whole grains, g/d	23.1 (51.1)	19.7 (40.4)	19.7 (40.1)	21.6 (43.2)	23.0 (46.5)	<0.001
Refined grains, g/d	93.9 (82.1)	121.9 (100.4)	129.5 (101.6)	141.5 (116.6)	168.3 (147.8)	<0.001
Legumes, g/d	3.5 (15.5)	8.7 (28.9)	14.2 (37.1)	20.3 (47.7)	29.0 (65.5)	<0.001*
Nuts, g/d	2.9 (12.4)	3.5 (13.9)	5.0 (19.2)	6.0 (18.2)	6.1 (17.2)	<0.001*
Milk, g/d	86.5 (195.0)	63.1 (97.6)	68.4 (103.1)	69.7 (100.4)	63.3 (100.0)	0.003*
Yoghurt, g/d	29.7 (60.4)	35.6 (63.4)	33.0 (60.8)	34.5 (63.4)	31.3 (59.3)	<0.001*
Cheese, g/d	17.7 (19.4)	24.9 (21.0)	32.2 (25.0)	43.1 (31.2)	67.4 (56.3)	<0.001*
Eggs, g/d	4.5 (10.8)	8.8 (16.2)	11.2 (20.1)	12.5 (18.6)	22.5 (36.0)	<0.001*
Seafood, g/d	13.0 (42.0)	19.9 (67.6)	25.4 (78.6)	28.8 (81.4)	29.5 (86.6)	<0.001*
Red meat, g/d	28.4 (51.0)	38.5 (58.8)	38.8 (60.9)	43.7 (66.1)	54.9 (83.4)	<0.001*
White meat, g/d	50.6 (112.3)	21.2 (42.4)	22.0 (52.4)	15.7 (38.5)	17.2 (49.3)	<0.001
Processed meats, g/d	15.6 (42.5)	14.8 (30.5)	13.0 (22.5)	13.2 (22.5)	14.9 (26.6)	<0.001*
Olive oil, g/d	4.4 (5.6)	8.4 (7.5)	14.8 (8.9)	22.4 (11.1)	45.0 (30.4)	<0.001*
Other vegetable fats, g/d	1.22 (5.2)	1.6 (4.5)	1.5 (5.0)	2.3 (6.4)	3.7 (14.4)	<0.001*
Animal fats, g/d	4.3 (10.0)	5.2 (13.7)	5.2 (9.8)	6.0 (14.6)	6.4 (18.4)	<0.001*
SSBs, g/d	104.1 (249.5)	84.1 (178.7)	78.2 (182.8)	77.0 (174.5)	92.3 (213.8)	<0.001*
Salty snacks, g/d	13.0 (68.1)	5.2 (35.4)	3.1 (15.7)	3.2 (19.4)	2.9 (21.6)	<0.001*
Sweets, g/d	68.2 (89.3)	54.8 (72.3)	49.3 (69.6)	52.0 (65.6)	49.0 (73.6)	<0.001*
Water, g/d	1209.8 (793.6)	1223.1 (744.9)	1261.0 (727.4)	1336.2 (731.9)	1396.6 (797.5)	<0.001
Coffee, g/d	178.0 (170.8)	172.1 (166.8)	160.9 (150.2)	170.2 (147.8)	157.7 (140.0)	<0.001*
Fast-food, g/d	121.1 (216.4)	58.6 (108.0)	51.0 (108.4)	41.3 (89.8)	38.6 (85.8)	<0.001
Nutrients						
Total energy, kcal/d	1839.0 (941.3)	1690.0 (789.4)	1764.7 (747.8)	1960.1 (752.6)	2403.8 (912.9)	<0.001*
Protein, %E	17.7 (7.5)	17.3 (5.5)	17.0 (5.6)	16.3 (4.5)	15.7 (4.4)	<0.001*
Carbohydrates, %E	50.8 (15.7)	49.8 (14.4)	47.6 (13.7)	46.0 (12.9)	43.0 (13.0)	<0.001*
Fat intake, %E	33.8 (10.5)	35.0 (9.6)	37.7 (9.1)	40.0 (9.5)	43.9 (9.8)	<0.001*

	Q1 (n=711)	Q2 (n=710)	Q3 (n=711)	Q4 (n=710)	Q5 (n=710)	P
SFA, %E	11.8 (4.9)	12.1 (4.3)	12.5 (4.0)	12.8 (4.1)	13.5 (4.1)	<0.001*
MUFA, %E	14.0 (5.7)	15.0 (5.3)	16.7 (5.3)	18.5 (5.6)	21.3 (6.4)	<0.001*
PUFA, %E	5.5 (4.5)	5.2 (3.2)	5.5 (3.0)	5.7 (2.6)	6.0 (2.8)	<0.001
Alcohol, g/d	8.6 (21.9)	7.9 (20.1)	6.9 (16.0)	6.7 (15.2)	8.1 (19.9)	<0.001
Dietary fiber (g/1000kcal)	14.0 (11.8)	14.3 (10.6)	14.4 (9.7)	14.6 (9.1)	14.9 (9.0)	<0.001

Data are presented as mean (SD). *Presence of linear trend.

MUFA, mono-unsaturated fatty acids; PUFA, poly-unsaturated fatty acids; SFA, saturated fatty acids

Table 4. Food, energy, and macronutrient intake across quintiles of adherence to the Western dietary pattern.

	Q1 (n=711)	Q2 (n=710)	Q3 (n=711)	Q4 (n=710)	Q5 (n=710)	P
Foods						
Fruits, g/d	188.7 (268.5)	135.5 (170.4)	118.1 (136.4)	105.5 (127.4)	94.4 (145.9)	<0.001
Non-starchy vegetables, g/d	157.5 (169.9)	159.8 (174.7)	147.9 (140.9)	156.2 (143.1)	147.2 (135.3)	<0.001*
Starchy vegetables, g/d	29.8 (72.6)	32.2 (68.2)	32.8 (68.2)	32.4 (80.8)	38.5 (122.1)	<0.001*
Whole grains, g/d	18.3 (30.3)	18.0 (31.8)	23.0 (45.5)	20.4 (45.3)	27.5 (61.5)	<0.001*
Refined grains, g/d	75.3 (66.0)	102.1 (81.0)	124.7 (98.4)	157.8 (116.8)	195.3 (149.9)	<0.001
Legumes, g/d	28.7 (63.3)	16.4 (44.9)	12.3 (35.2)	8.9 (28.8)	9.3 (32.2)	<0.001*
Nuts, g/d	2.4 (8.8)	3.4 (11.8)	3.6 (12.1)	6.0 (20.0)	8.3 (23.7)	<0.001*
Milk, g/d	56.5 (93.6)	62.7 (99.9)	64.3 (99.3)	75.3 (103.2)	92.3 (196.5)	0.206
Yoghurt, g/d	52.6 (73.6)	36.0 (64.6)	28.6 (55.5)	26.6 (55.6)	20.1 (50.5)	<0.001*
Cheese, g/d	17.6 (20.4)	28.7 (25.7)	34.1 (27.4)	43.6 (35.0)	61.4 (54.2)	<0.001*
Eggs, g/d	5.4 (12.1)	8.5 (16.9)	11.7 (20.4)	13.0 (22.6)	20.8 (33.1)	<0.001*
Seafood, g/d	42.8 (114.7)	29.2 (81.9)	15.8 (46.0)	14.8 (47.0)	13.9 (44.7)	<0.001*
Red meat, g/d	17.6 (33.3)	28.5 (43.6)	40.8 (58.3)	52.3 (74.6)	65.2 (89.8)	<0.001
White meat, g/d	11.8 (36.7)	17.1 (37.4)	28.9 (67.4)	30.9 (75.7)	38.1 (91.9)	<0.001*
Processed meats, g/d	2.4 (6.9)	6.0 (11.5)	9.8 (13.5)	15.6 (18.9)	37.8 (54.4)	<0.001*
Olive oil, g/d	17.2 (25.3)	18.6 (19.5)	18.4 (20.2)	19.5 (18.8)	21.4 (21.2)	<0.001
Other vegetable fats, g/d	0.8 (2.4)	1.2 (3.3)	1.5 (4.4)	5.6 (8.2)	15.8 (26.2)	<0.001*
Animal fats, g/d	0.8 (2.2)	2.0 (3.6)	3.0 (4.9)	5.6 (8.2)	15.8 (26.2)	<0.001*

	Q1 (n=711)	Q2 (n=710)	Q3 (n=711)	Q4 (n=710)	Q5 (n=710)	P
SSBs, g/d	24.9 (76.6)	55.0 (121.0)	69.1 (144.6)	106.9 (217.0)	179.7 (318.7)	<0.001
Salty snacks, g/d	0.8 (6.7)	2.1 (13.8)	3.2 (21.6)	5.4 (35.3)	16.0 (70.5)	<0.001*
Sweets, g/d	25.1 (37.3)	39.3 (51.1)	55.7 (68.6)	65.3 (79.5)	88.0 (103.3)	<0.001
Water, g/d	879.0 (604.7)	1157.3 (608.6)	1283.8 (679.9)	1457.0 (741.2)	1650.1 (904.8)	<0.001
Coffee, g/d	101.3 (98.0)	143.5 (133.6)	163.1 (137.3)	198.1 (163.0)	232.9 (195.6)	<0.001
Fast-food, g/d	35.9 (106.6)	50.2 (101.6)	60.1 (118.9)	76.6 (158.6)	88.0 (166.2)	<0.001*
Nutrients						
Total energy, kcal/d	1301.4 (564.6)	1572.8 (557.8)	1804.3 (587.8)	2198.9 (728.5)	2780.9 (972.1)	<0.001*
Protein, %E	17.2 (6.4)	16.7 (6.0)	16.9 (5.5)	16.8 (5.2)	16.5 (5.1)	0.029*
Carbohydrates, %E	48.6 (14.8)	48.4 (15.0)	47.8 (13.4)	47.5 (14.1)	44.9 (13.7)	<0.001*
Fat intake, %E	37.2 (10.9)	37.8 (10.7)	37.6 (9.6)	38.2 (10.0)	39.5 (10.6)	<0.001*
SFA, %E	11.2 (4.3)	12.1 (4.3)	12.8 (4.1)	13.1 (4.3)	13.4 (4.2)	<0.001
MUFA, %E	18.0 (7.1)	17.5 (6.4)	16.6 (5.6)	16.6 (5.8)	16.9 (6.1)	<0.001
PUFA, %E	5.2 (2.2)	5.5 (3.9)	5.4 (3.0)	5.6 (3.1)	6.3 (3.8)	<0.001*
Alcohol, g/d	2.2 (5.9)	5.5 (13.1)	6.4 (13.3)	8.2 (15.8)	15.9 (32.2)	<0.001
Dietary fiber (g/1000kcal)	15.7 (9.6)	15.3 (10.9)	14.1 (9.9)	14.2 (10.3)	12.7 (9.6)	<0.001*

Data are presented as mean (SD). *Presence of linear trend.

MUFA, mono-unsaturated fatty acids; PUFA, poly-unsaturated fatty acids; SFA, saturated fatty acids

Table 5. Food, energy, and macronutrient intake across quintiles of adherence to the Prudent dietary pattern.

	Q1 (n=711)	Q2 (n=710)	Q3 (n=711)	Q4 (n=710)	Q5 (n=710)	P
Foods						
Fruits, g/d	42.3 (75.0)	82.0 (99.7)	118.8 (127.4)	155.5 (141.9)	243.8 (295.2)	<0.001*
Non-starchy vegetables, g/d	127.5 (128.5)	163.1 (166.3)	147.2 (132.4)	157.0 (152.5)	173.7 (178.8)	<0.001
Starchy vegetables, g/d	19.2 (50.5)	28.2 (62.1)	32.5 (71.0)	34.4 (70.1)	51.5 (138.3)	<0.001*
Whole grains, g/d	3.0 (10.5)	7.2 (15.9)	11.9 (20.2)	23.0 (28.9)	62.0 (77.5)	<0.001*
Refined grains, g/d	168.8 (150.2)	143.4 (110.2)	132.5 (101.2)	109.2 (90.5)	101.3 (97.3)	<0.001
Legumes, g/d	16.6 (49.1)	16.4 (41.5)	13.3 (38.6)	15.2 (41.7)	14.2 (45.1)	<0.001*
Nuts, g/d	1.6 (8.1)	2.0 (7.7)	3.7 (15.1)	5.6 (17.1)	10.7 (25.5)	<0.001

	Q1 (n=711)	Q2 (n=710)	Q3 (n=711)	Q4 (n=710)	Q5 (n=710)	P
Milk, g/d	39.7 (76.1)	43.6 (78.2)	71.3 (103.9)	78.9 (109.7)	117.8 (199.8)	<0.001
Yoghurt, g/d	2.8 (14.2)	8.2 (26.4)	14.1 (34.8)	44.0 (60.0)	95.0 (85.9)	<0.001
Cheese, g/d	34.9 (34.6)	38.1 (41.6)	37.2 (36.5)	36.6 (38.1)	38.5 (37.0)	<0.001
Eggs, g/d	10.8 (21.9)	12.2 (24.7)	11.9 (21.0)	11.9 (21.7)	12.7 (24.3)	<0.001*
Seafood, g/d	11.0 (43.1)	20.1 (60.2)	23.9 (77.9)	31.4 (89.6)	30.2 (83.5)	<0.001*
Red meat, g/d	63.3 (85.1)	44.0 (64.7)	38.1 (62.0)	28.4 (45.4)	30.5 (57.7)	<0.001
White meat, g/d	10.9 (30.4)	15.6 (34.7)	21.2 (47.8)	26.4 (54.9)	52.7 (115.8)	<0.001*
Processed meats, g/d	21.1 (49.6)	14.0 (24.2)	13.1 (21.9)	11.4 (20.6)	11.9 (21.2)	<0.001*
Olive oil, g/d	17.5 (26.4)	20.7 (20.5)	18.5 (18.6)	18.8 (19.0)	19.4 (20.4)	<0.001
Other vegetable fats, g/d	2.2 (6.7)	2.0 (6.6)	2.4 (8.2)	2.2 (12.0)	1.5 (5.1)	<0.001
Animal fats, g/d	5.9 (12.0)	4.9 (12.9)	5.4 (12.6)	5.7 (14.8)	5.2 (15.9)	<0.001*
SSBs, g/d	210.0 (348.5)	87.9 (164.2)	51.1 (111.4)	39.6 (92.8)	46.8 (120.2)	<0.001
Salty snacks, g/d	9.2 (47.4)	6.3 (43.0)	3.8 (32.8)	4.1 (30.4)	4.1 (30.6)	<0.001*
Sweets, g/d	78.9 (95.0)	56.3 (75.5)	50.6 (61.8)	49.3 (70.3)	38.1 (60.1)	<0.001
Water, g/d	1075.9 (665.4)	1180.8 (694.2)	1289.0 (731.0)	1328.1 (713.0)	1553.2 (902.7)	<0.001*
Coffee, g/d	244.4 (193.8)	177.2 (141.0)	152.6 (141.4)	135.6 (129.1)	129.0 (135.7)	<0.001
Fast-food, g/d	165.8 (231.6)	61.1 (102.3)	35.4 (69.6)	30.0 (63.7)	18.3 (52.7)	<0.001*
Nutrients						
Total energy, kcal/d	2416.1 (990.9)	1887.9 (817.7)	1718.1 (736.0)	1710.6 (741.8)	1924.2 (844.3)	<0.001
Protein, %E	15.6 (5.3)	16.1 (4.4)	16.7 (6.2)	16.9 (5.2)	18.7 (6.5)	<0.001*
Carbohydrates, %E	49.6 (15.6)	47.4 (14.5)	46.9 (14.0)	46.7 (13.1)	46.7 (13.8)	<0.001
Fat intake, %E	36.1 (10.8)	38.8 (10.3)	39.1 (10.0)	39.1 (10.3)	37.4 (10.2)	<0.001
SFA, %E	12.4 (4.6)	12.6 (4.3)	13.0 (4.2)	12.7 (4.3)	12.0 (4.1)	0.002
MUFA, %E	15.7 (6.2)	17.8 (6.4)	17.6 (6.0)	17.9 (6.4)	16.6 (5.8)	<0.001
PUFA, %E	5.5 (3.9)	5.4 (2.6)	5.6 (3.7)	5.6 (2.5)	5.9 (3.4)	<0.001*
Alcohol, g/d	16.9 (31.4)	7.9 (15.2)	5.1 (12.7)	3.9 (9.4)	4.5 (13.8)	<0.001
Dietary fiber (g/1000 kcal)	14.8 (12.1)	14.7 (10.9)	14.1 (9.8)	14.2 (8.8)	14.3 (8.6)	<0.001*

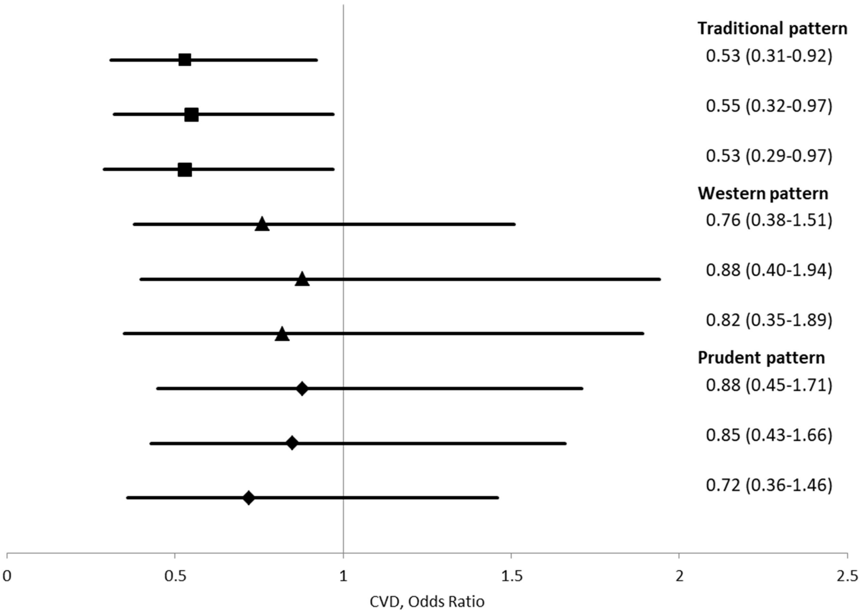
Data are presented as mean (SD). *Presence of linear trend.

MUFA, mono-unsaturated fatty acids; PUFA, poly-unsaturated fatty acids; SFA, saturated fatty acids

Associations with cardiovascular disease and related conditions

Multivariable logistic regression analysis showed that highest adherence to the Traditional pattern was inversely associated with total CVD (OR: 0.53; 95%CI: 0.31-0.92) (**Figure 1**); this association remained significant after additional adjustment for energy intake (0.55; 0.32-0.97) and energy intake and other risk factors (0.53; 0.29-0.97). A marginally non-significant inverse association was also observed between the Traditional pattern and CHD, after full adjustment (0.54; 0.27-1.07) (**Table 6**). Participants with highest Western pattern score were 49% more likely to have elevated cholesterol/triglycerides compared to those at the lowest quintile (1.49; 1.08-2.05); further adjustments slightly increased these odds but did not appreciably change the observed association. No significant associations were found between highest adherence to the Western pattern and CHD (0.71; 0.27-1.87) or total CVD (0.82; 0.35-1.89). The Prudent dietary pattern was not significantly associated with any of the CVD outcomes, although a tendency towards a positive association with high levels of cholesterol/triglycerides was observed (1.33; 0.96-1.88).

Figure 1. Association of empirically-derived dietary patterns with total cardiovascular disease.



Results are presented by dietary pattern (■Traditional, ▲Western,◆Prudent) as odds ratio (95%CI) from logistic regression analysis adjusted for age (years) and sex (Model 1), age, sex, and energy intake (kcal/d) (Model 2), and age, sex, physical activity (moderately intense or intense, min/d), education level (≤6, 6-12, and ≥12 years), percent of energy intake (%E) from saturated fat, presence of diabetes, smoking status (current smoker, former smoker, never smoked), alcohol consumption (drinks per day), and Body Mass Index (kg/m^2) (Model 3). Total cardiovascular disease (CVD) included coronary heart disease (CHD) (ICD-10 code: I20-I25) and stroke (I60-I67, I69.0-I69.4).

Table 6. Association of empirically-derived dietary patterns with cardiovascular risk factors and coronary heart disease.

CVD outcomes[1]	**N**	**Traditional**				**Western**				**Prudent**			
		Q1	**Q5**		P-value	**Q1**	**Q5**		P-value	**Q1**	**Q5**		P-value
		OR	OR	95% CI		OR	OR	95% CI		OR	OR	95% CI	
Dyslipidemia													
Model 1	3,395	1.00	0.87	0.65, 1.17	0.356	1.00	1.49	1.08, 2.05	0.014	1.00	1.20	0.88, 1.62	0.254
Model 2	3,395	1.00	0.84	0.62, 1.13	0.253	1.00	1.57	1.09, 2.28	0.017	1.00	1.23	0.90, 1.67	0.199
Model 3	3,168	1.00	0.86	0.63, 1.19	0.365	1.00	1.52	1.02, 2.26	0.039	1.00	1.33	0.96, 1.85	0.089
Hypertension													
Model 1	3,509	1.00	1.31	0.92, 1.87	0.139	1.00	1.32	0.89, 1.96	0.171	1.00	0.86	0.58, 1.26	0.428
Model 2	3,509	1.00	1.29	0.89, 1.86	0.175	1.00	1.31	0.82, 2.08	0.258	1.00	0.87	0.59, 1.29	0.496
Model 3	3,265	1.00	1.35	0.90, 2.00	0.142	1.00	1.16	0.70, 1.93	0.554	1.00	0.98	0.65, 1.48	0.918
CHD													
Model 1	3,526	1.00	0.57	0.30, 1.07	0.083	1.00	0.73	0.33, 1.58	0.422	1.00	1.04	0.48, 2.27	0.919
Model 2	3,526	1.00	0.60	0.31, 1.15	0.125	1.00	0.79	0.32, 1.98	0.616	1.00	1.00	0.46, 2.21	0.987
Model 3	3,275	1.00	0.54	0.27, 1.07	0.076	1.00	0.71	0.27, 1.87	0.491	1.00	0.95	0.42, 2.16	0.912

P-values refer to logistic regression analysis, adjusted for age (years) and sex (Model 1), age, sex, and energy intake (kcal/d) (Model 2), and age, sex, physical activity (moderately intense or intense, min/d), education level (≤6, 6-12, and ≥12 years), percent of energy intake (%E) from saturated fat, presence of diabetes, smoking status (current smoker, former smoker, never smoked), alcohol consumption (drinks per day), and Body Mass Index (kg/m^2) (Model 3).

[1] Total cardiovascular disease (CVD) outcomes include dyslipidemia (ICD-10 code: E78.0-E78.5), hypertension (I10), and coronary heart disease (CHD) (I20-I25).

CI, Confidence interval; OR, Odds Ratio; Q, Quintile.

Discussion

The relationship between empirically-derived dietary patterns and CVD risk has been investigated previously;[28] yet due to differences in dietary pattern composition, partially explained by study population characteristics and variations in eating habits, direct comparisons between studies and generalizability of evidence is challenging.[29] In the present study, a proxy Mediterranean pattern, named Traditional, was the primary dietary pattern identified among Greek adults. The Traditional pattern had strong positive loadings for some of the fundamental components of the Mediterranean diet,[30-32] such as olive oil and non-starchy vegetables, but weak loadings for others, including whole grains, fish, and legumes.[20] Moreover, a higher unprocessed red meat intake was observed comparing highest to lowest adherence to this pattern. These findings suggest a westernization of the typical Mediterranean diet, while they are consistent with compiling evidence suggesting that the Mediterranean diet is now progressively disappearing in the Mediterranean countries.[33-37]

Remarkably, although the identified Traditional pattern deviated from the Mediterranean diet, which has been consistently found to be inversely associated with CVD incidence,[16,38] it was still associated with reduced risk of CVD presence. This may be attributed to the observed higher intakes of foods with established protective effects against CVD, such as fruits, vegetables, and legumes, and lower intakes of foods with harmful effects, such as SSBs;[39] in contrast, neither unprocessed red meat nor cheese have been identified as etiologic risk factors for CHD or stroke. Our findings suggest that the recently formed Traditional Greek diet, which combines cardioprotective components of the Mediterranean diet and potentially harmful components of the traditional and westernized local cuisine, may still have a CVD benefit.

In this study, the Western dietary pattern was associated with greater likelihood of established dyslipidemia, but it was not associated with the presence of hypertension, CHD or total CVD among Greek adults. Both national and international findings have reported positive associations for Western/unhealthy dietary patterns and CVD risk,[40-42] yet the majority of the evidence suggests lack of significant association between unhealthy patterns and hypertension, CHD or CVD risk.[8-10,12,43] In a recent meta-analysis of 7 prospective cohorts with no significant heterogeneity, including 182,007 participants and 5,543 CVD deaths, no significant association was reported between Western/unhealthy dietary patterns and CVD mortality (RR: 0.99; 95% CI: 0.91-1.08).[10] Similarly, another meta-analysis of 9 prospective cohorts, including 351,656 individuals and 4,962 CHD cases, showed no association between Western/unhealthy patterns and CHD risk (1.05; 0.86-1.27) comparing highest to lowest adherence; heterogeneity across studies was substantially high.[9] More recent evidence from prospective cohorts are mixed, suggesting either no[44] or an inverse[45,46] association of unhealthy patterns with CVD incidence. Several plausible explanations are suggested for this unexpected, in terms of diet quality, null association; these include methodological concerns, such as subjectivity of PCA steps or unknown/unmeasured potential confounders, and population-specific aspects. In this study, participants with highest vs. lowest adherence to the Western pattern, were associated with higher intakes of foods with high nutritional value and certain protective roles, such as rich in PUFA nuts and whole grains, both of which have been shown to have beneficial cardiometabolic health effects.[39] The consumption of such foods may counteract, at some level, the harmful effects of the unhealthy foods of the identified Western pattern, potentially attenuating a significant association with CVD and/or related conditions.[19]

Interestingly, no significant associations were reported for the Prudent pattern, which was the healthiest among the identified patterns. Although there are prospective cohorts that have similarly not found an association,[44] our finding is not consistent with the majority of available evidence from prospective and cross-sectional studies showing an inverse association between healthy patterns and CVD.[8-10,46] Based on a meta-analysis of 8 prospective cohorts, including 187,434 individuals, the Prudent/healthy dietary pattern was inversely associated with CVD mortality (0.81; 0.75-0.87); however, there was substantial heterogeneity observed across the studies.[10] Similarly, a meta-analysis of 12 prospective cohorts of no significant heterogeneity, including 409,780 individuals and 6,298 cases, found an inverse association between Prudent/healthy patterns and CHD risk (0.80; 0.74-0.87) comparing highest to lowest adherence.[9] The lack of association between our Prudent pattern and CVD outcomes, might be partially explained by the unique characteristic of this study that two patterns -Traditional and Prudent- could qualify as healthy. Usually, only one identified pattern is characterized as healthy per study. Previous studies have identified Traditional additionally to healthy patterns; yet, these were closer to Western/unhealthy patterns,[46,47] unlike the proxy Mediterranean Traditional pattern of this study. Furthermore, no Greek study was included in the aforementioned meta-analyses, hence no referent association between dietary patterns and CVD is available for the Greek population.

There are several strengths in our study. HNNHS is the first study in Greece to reveal the associations of empirically-derived dietary patterns and CVD presence in a nationally representative sample of adults with a broad age range. The dietary data collection fully covered seasonality in Greece; hence, potential seasonal changes in food consumption were accounted for. The dietary data used were collected by multiple 24hR, administered by the AMPM method, which standardizes the description of the reported food items and, therefore, maximizes the accuracy of the estimated food consumption. Data were fully adjusted for the key known risk factors for CVD; potential confounding cannot be completely excluded though.

Some limitations of this study should be also considered. First, this is a cross-sectional analysis and our findings do not infer causality between dietary patterns and CVD; yet this is a national study, which informs country-specific public health policies and nutritional interventions. Second, the presence of CVD and CVD-related conditions were self-reported; although self-reported and recorded clinical measures have been found to be consistent,[48] our findings might be different if this information was based on biomarkers and/or clinical examination.[49] Third, PCA, a method with proven validity and reproducibility,[50,51] involves a high degree of subjectivity throughout the analytical process, including food group construction, number of components to retain, and interpretation of identified patterns; hence, different decisions could alter the observed results.[52] Finally, the total variance explained by the dietary patterns was low; yet, this is not uncommon among similar studies.[38,47,53]

In conclusion, this study identified three dietary patterns with different strengths of association with CVD presence among Greek adults. Adherence to a Traditional -proxy Mediterranean- dietary pattern, was associated with lower odds of total CVD presence, whereas no significant associations were observed between the Western and Prudent patterns and CHD or CVD presence. Our findings suggest that the variability of food intake combinations may potentially hold a key role in the development of CVD. Given that dietary pattern identification is based on population-specific correlations of dietary habits, the analysis of dietary patterns could be considered as a valid measure of dietary intake in the longer term. Yet, the heterogeneity of dietary habits within a population, further affected by demographic and socioeconomic characteristics, results in numerous minor dietary patterns. Therefore, further research, particularly prospective cohort studies, is warranted in Greece to better understand these patterns, to evaluate the diet-disease relationship, and to predict how the population's food consumption trends will affect the country's disease burden over time.

Acknowledgements

We thank all field workers (in alphabetical order based on surname):

Ioanna Adami, Aggeliki Anastasiou, Elisavet Anestiadou, Nikolaos Altanis, Georgios Argyropoulos, Euaggelia Arvanitidou, Anastasios Barounis, Alexandra Basdeki, Polychronis Bazakidis, Dimitra Borsa, Vasileia Chatzistergiou, Theodoros Chrysanidis, Konstantinos Daskalou, Chrysaugi Galanaki, Chrysanthi Gerasimatou, Arriana Gkouvi, Lampros Grampsas, Eleni Ioannidi, Vasiliki Kanaki, Eustratios Karagiannidis, Eirini Kasapidou, Vasiliki Katseni, Georgios Koktsidis, Eirini Konstantakou, Andronikos Kostakidis, Sotiria Kottara, Eleutheria Kourliti, Maria Kourtidou, Aikaterini Lymperopoulou, Nikoleta Markoglou, Aikaterini Markou, Anna Mauromanoli, Panagiota Merou, Areti Miha, Marianna Moira, Ioannis Moschakis, Dimitra Mougopetrou, Konstantina Mouliou, Andromachi Mourtzouhou, Vasiliki Moustakaki, Vissarios Moutsanas, Maria-Aggeliki Mpoulet, Evangelia Nanou, Ioannis Nikolaidis, Giannos-Aggelos Nikolaou, Sakellarios Panagiotakis, Eirini Panagiotou, Panagiotis Papadopoulos, Vasiliki Papageorgiou, Nikolaos Papaspanos, Olga Papazisi, Euthymia-Iro Pappa, Eufrosyni Patiraki, Konstantinos Petsanis, Maria-Christina Polychronopoulou, Nikolitsa Psylia, Alexandros Sachinidis, Avraam Sarafopoulos, Paraskevi Seferidi, Christos Sifnaios, Dimitra Stauropoulou, Myrto Stavrou, Chrysanthi Tatsi, Nena Theodoridou, Anna Theou, Christina-Yakinthi Tzotziou, Georgios Vergos, Agapi Vlachou, Anastasia Xatziapostolou, Iliana Xatzifragou, Adela Zana.

Conflict of Interest Statement

None.

Funding Sources

This work was supported by Greece and the European Union (European Social Fund) under the Operational Program "Human Resources Development 2007-2013”.

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5. General Conclusions

This PhD thesis provides the first analysis to explore the dietary patterns in a nationally representative sample of adults in Greece. Using PCA, three main dietary patterns -Traditional, Western, and Prudent- were derived overall and by sex, with distinct food consumption behaviors, as well as demographic, lifestyle, and mental health determinants; a fourth dietary pattern was identified in women. The Traditional pattern was significantly associated with 47% fewer odds of total CVD presence; the Western dietary pattern was associated with 48% more odds of established dyslipidemia; whereas, the Prudent pattern was not associated with any CVD outcome.

In this analysis, we identified both patterns that are consistently reported in the literature; the healthy "Prudent" pattern and the unhealthy Western pattern.[8,11,12,60,61] Yet, the pattern that explained the greatest part of the total variance was the Traditional pattern. This pattern was considered as a proxy Mediterranean dietary pattern because, although it effectively had high loadings for fundamental components of the Mediterranean diet,[108-110] such as non-starchy vegetables and olive oil, it had weak loadings for others, such as whole grains, fish, and legumes. On the contrary, it had high loadings for representative foods of the Greek cuisine, such as cheese. These findings suggest a westernization of the typical Mediterranean diet and are consistent with compiling evidence suggesting that the Mediterranean diet is now progressively disappearing in the Mediterranean countries.[111-114]

Despite its deviation from the Mediterranean diet, which has been consistently found to be inversely associated with CVD incidence,[23,115] and the high caloric intake, the Traditional pattern was still associated with 47% less odds of total CVD presence. There are several explanations for these findings. First, individuals with highest vs. lower adherence to this pattern had higher dietary intakes of foods with established protective effects against CVD, such as fruits, vegetables, legumes, seafood, and nuts, and lower intakes of foods with harmful effects, such as SSBs.[116] Second, evidence from prospective cohorts and RCTs are inconsistent regarding the identification of unprocessed red meat as etiologic risk factor for CHD or stroke.[116] Third, the Traditional pattern is high-fat low-carbohydrates dietary pattern; recent evidence suggest that healthy low-carbohydrate diets have beneficial associations with CVD risk factors, as high intake of carbohydrates can be indirectly harmful for cardiovascular health.[117,118] The findings of the current analysis suggest that the recently formed Traditional Greek diet, which combines cardioprotective components of the Mediterranean diet along with neutral or potentially harmful diet components, may still have a CVD benefit.

The Western pattern identified in this analysis is in line with similar patterns identified across literature. Highly adherent individuals were overall characterized by high intakes of foods with robust evidence regarding their harmful effect on CVD risk, such as processed meats and SSBs;[116] lower intakes were reported for foods with protective role against CVD, such as fruits, legumes, and seafood. In terms of energy and macronutrient intake, highest adherence to the Western pattern was linked to higher intakes of energy, %E from SFA, and alcohol, but also with %E from PUFA.

The Western dietary pattern was associated with greater likelihood of established dyslipidemia among Greek adults, but it was not associated with the presence of hypertension, CHD or total CVD. Existing evidence across literature is unclear; although positive associations for Western/unhealthy dietary patterns and CVD risk have been reported in both national and international studies,[31,119,120] the majority of the evidence suggests lack of significant association between unhealthy patterns and hypertension, CHD or CVD risk.[11-13,15,121] In a recent meta-analysis of 7 prospective cohorts with no significant heterogeneity, including 182,007 participants and 5,543 CVD deaths, no significant association was reported between Western/unhealthy dietary patterns and CVD mortality (RR: 0.99; 95% CI: 0.91-1.08).[13] Similarly, another meta-analysis of 9 prospective cohorts, including 351,656 individuals and 4,962 CHD cases, showed no association between Western/unhealthy patterns and CHD risk (1.05; 0.86-1.27) comparing highest to lowest adherence; heterogeneity across studies was substantially high.[12] More recent evidence from prospective cohorts are mixed, suggesting either no[101] or an inverse[122,123] association of unhealthy patterns with CVD incidence. Several plausible explanations are suggested for this unexpected, in terms of diet quality, null association; these include methodological concerns, such as subjectivity of PCA steps or unknown/unmeasured potential confounders, and population-specific aspects. In this study, individuals with highest vs. lowest adherence to the Western pattern, were more likely to be of younger age; CVD risk has been positively associated with increasing age.[88] Moreover, highly adherent individuals were associated with higher intakes of foods with high nutritional value and certain protective roles, such as rich in PUFA nuts and whole grains, both of which have been shown to have beneficial cardiometabolic health effects.[116] The consumption of such foods may counteract, at some level, the harmful effects of the unhealthy diet components of the identified Western pattern, potentially attenuating a significant association with CVD and/or related conditions.[61] Therefore, the findings of the current analysis are in line with existing evidence suggesting null association of Western patterns with CVD, further highlighting the potential importance of food/nutrient interactions in attenuating otherwise expected harmful associations.

The Prudent pattern loaded positively for fruits, whole grains, yoghurt, and white meat, and negatively for fast-food. This pattern was similar in the overall population and by sex, with additional negative loadings for SSBs in women and alcohol in men. Highest adherence to the Prudent pattern had optimal macronutrient intakes, such as lower caloric intake, lower %E from carbohydrates and SFA, and higher protein and unsaturated fat intake. Interestingly, no significant associations were reported for the Prudent pattern, which was the healthiest among the identified patterns. These findings are not consistent with existing evidence from prospective cohorts and cross-sectional studies, which show an inverse association between healthy patterns and CVD;[11-13,123] yet there are prospective cohort studies that have similarly found no association.[101] Based on a meta-analysis of 8 prospective cohorts, including 187,434 individuals, the Prudent/healthy dietary pattern was inversely associated with CVD mortality (0.81; 0.75-0.87); however, there was substantial heterogeneity observed across the studies.[13] Similarly, a meta-analysis of 12 prospective cohorts of no significant heterogeneity, including 409,780 individuals and 6,298 cases, found an inverse association between Prudent/healthy patterns and CHD risk (0.80; 0.74-0.87) comparing highest to lowest adherence.[12] The lack of association between our Prudent pattern and CVD outcomes, might be partially explained by the unique characteristic of this study that two patterns -Traditional and Prudent- could qualify as healthy. Usually, only one identified pattern is characterized as healthy per study. Previous studies have identified Traditional additionally to healthy patterns; yet, these were closer to Western/unhealthy patterns,[59,123] unlike the proxy Mediterranean Traditional pattern of this study.

The fourth dietary pattern that was identified only in women, was a Snack-type pattern, described by ready to eat or easy to prepare foods; it was characterized by higher intakes of artificially sweetened beverages, nuts, sweets, and salty snacks. Few studies have previously identified a group of consumers characterized by high consumption of foods commonly classified as snacks, such as chips, crackers, beverages, desserts, and confectionary.[60,63] The identification of such pattern in this study could be partially explained by the level of aggregation of chosen foods, which identified groups of snacks (e.g., salty, sweets) separately. Notably, although the identified Snack-type pattern had positive loadings for salty snacks, sweets, and nuts, there was a tendency for counterbalancing the high-caloric content of these foods with sweeteners.

The description of dietary patterns by demographic and lifestyle characteristics, showed both consistent and contradictory to the existing literature findings. In line with previous findings, adherent individuals to the healthier patterns had better dietary habits in terms of breakfast consumption frequency and eating food prepared outside home, were less likely to smoke and more likely to exercise more. This analysis also showed that the socio-economic status had a strong influence on food consumption. However, the direction of the results contradicted previous findings; the Western and Snack-type patterns were associated with positive employment status and high education level, whereas the opposite was observed for the Traditional and Prudent patterns. Existing evidence shows that higher socio-economic and educational status is associated with healthier food consumption, such as fruit, vegetables, and whole grains, and lower socio-economic and educational status is associated with processed and unprocessed meats and energy-dense food consumption, such as fast-food and sweets.[59,60,124-126] These contradictory findings are complemented by the BMI results, with higher prevalence of overweight and obesity being reported for the

Traditional and lower for the Western and Snack-type ones. A potential explanation for these observations is the overall profile of the individuals adhering to each of the patterns. Women and men adhering to the Western pattern are considerably younger, and in their productive age, as indicated by their employment status; therefore, their energy requirements would be expected to be higher compared to older and/or potentially unemployed adults, hence the caloric intake, despite high for this pattern, might still not be enough. Moreover, these results refer to a period of national economic crisis; recession periods have been associated with lower diet quality, deterioration of dietary habits, and lower adherence to the Mediterranean diet.[127,128] Adherent to the Traditional pattern individuals were more likely to reside outside the urban Attica area, potentially with higher access to agricultural products from own or close environment production; therefore, olive oil and vegetables could have been obtained at no or low cost, while other healthy foods, such as seafood and whole grains that are more expensive were not consumed in high amounts. However, since there are no available nationally representative data in Greece referring to a time point before the recession, no safe assumptions can be made.

An interesting finding of this analysis pertaining to mental health and dietary habits is that depression is positively associated with high adherence to the Snack-type pattern in women and to the Western pattern in men. Currently, the evidence on the association of Western-type patterns and the likelihood of depression is conflicting, with studies reporting either a positive or no association, mainly due to differences in study characteristics and methodological limitations.[129,130] Similarly, there is limited evidence for the relationship of sleep disorders and dietary patterns suggesting that Prudent/healthy patterns have been associated with higher sleep quality and lower prevalence of sleep disorders;[77] the findings of this analysis are in line with these observations. The suggested mechanisms underlying this finding include mainly tryptophan, an amino-acid that is precursor to sleep-promoting hormones; higher in protein dietary patterns, provide greater amounts of tryptophan, leading potentially to better sleep quality. Overall, this analysis suggests that there is a potential association between mental health, sleep quality and dietary patterns, which warrants further research.

Our study had several strengths. This is the first analysis to derive dietary patterns, using PCA, in a nationally representative sample of Greek adults with broad age range, and to investigate the associations of the identified patterns with CVD presence. The data collection period covered more than one year and a half, taking into account the seasonal consumption of certain foods, and capturing the exposure to foods consumed during certain periods (different seasons, holidays). The source of dietary data was multiple 24hR, rather than food frequency questionnaires that are commonly used for the identification of dietary patterns.[11,131,132] Although 3-7 days food records are considered as the gold standard, we used the AMPM to administer our 24hR, a method that maximizes the accuracy of the reported food consumption by limiting the omission of potentially forgotten foods and related administration errors, while standardizing the description of the various food items. Different levels of food aggregation were used, which led to distinguishing and better characterizing the Snack-type dietary pattern that had been confounded in previous studies. The dietary patterns were derived by PCA, a data-driven method used to investigate dietary patterns in various populations globally.[28,59,133,134] In Greece, PCA has been previously used to investigate dietary patterns,[31,62,82,135] but it has never been applied to identify dietary patterns of a representative sample of adults. A wide range of demographic, and lifestyle variables were included to characterize the derived dietary patterns. Data were fully adjusted for the main known risk factors for CVD; potential confounding cannot be completely excluded though.

The limitations of this analysis should be also considered. This is a cross-sectional study hence our findings do not infer causality between dietary patterns and CVD. The presence of CVD and CVD-related conditions was self-reported, and, although consistency between self-reported and recorded clinical measures has been previously reported,[136] our findings might not be the same if this information was based on biomarkers or clinical examination.[137] PCA, despite being a data-driven method with reasonable reproducibility and validity,[27,28] it still involves a high degree of subjectivity throughout the analytical process that could result in different outcomes based on different decisions.[34] The identified dietary patterns explained a low percentage of the total variance in dietary intake, which is, nonetheless, similar with findings in other studies.[59,60,77,115,133] The amount of explained variance largely depends on the number of food groups included in the PCA, and it decreases with greater numbers of food groups;[138] yet our findings, from the analysis of 36 food groups, were still similar to others of 20 food groups.[133] Moreover, we had a large percentage of energy intake mis-reporters, mainly under-reporters, consistent with what has been previously reported. Mis-reporters were included in the main analysis, as suggested by EFSA;[43] in sensitivity analyses these were excluded, but the derived patterns remained generally the same.

In conclusion, three main dietary patterns were identified among Greek adults with distinct food consumption characteristics, lifestyle determinants, and different strengths of association with CVD outcomes. Adherence to a Traditional -proxy Mediterranean- dietary pattern, was associated with lower odds of total CVD presence, whereas no significant associations were observed between the Western and Prudent patterns and CHD or total CVD presence. Our findings suggest that the variability of food intake combinations may potentially hold a key role in the development of CVD. Given that dietary pattern identification is based on population-specific correlations of dietary habits, the analysis of dietary patterns could be considered as a valid measure of dietary intake in the longer term. Yet, the heterogeneity of dietary habits within a population, further affected by demographic and socioeconomic characteristics, results in numerous minor dietary patterns. Therefore, further research, particularly prospective cohort studies, is warranted in Greece to better understand these patterns, to evaluate the diet-disease relationship, and to predict how the population's food consumption trends will affect the country's disease burden over time.

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