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A Standardized Assessment of Processed Red Meat and Processed Poultry Intake in the US Population Aged ≥2 Years Using NHANES

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ABSTRACT

Background: Standardized methods are needed to investigate intake patterns of processed meat subtypes, considering health concerns surrounding processed meat intake.

Objectives: The objectives of this study were to create a standardized method of disaggregating processed meat into processed red meat and processed poultry and describe intake patterns of the US population aged ≥2 y.

Methods: Two researchers independently manually disaggregated processed meat from the Food Patterns Equivalents Database into processed red meat and processed poultry based on available information from the Foods and Nutrient Database for Dietary Studies. We created an SAS program (called Processed Meat Categories) to mimic the manual coding. We used the program to describe intake patterns and trends over time of processed red meat and processed poultry using 24-h recalls from 2007–2008 through 2017–2018 NHANES data with SAS survey-weighted procedures for complex surveys.

Results: The SAS program had high agreement with the manual code (Pearson concordance correlation ≥0.95). Of the US population aged ≥2 y, 46.8% (95% CI: 45.3, 48.2%) reported consuming any processed meat, 42.5% (95% CI: 41.0, 43.9%) reported consuming processed red meat, and 11.3% (95% CI: 10.2, 12.4%) reported consuming processed poultry. Most [74.1 ± 0.13% (SEM)] processed meat reported was red meat compared with poultry, and 32.1 ± 0.01% of total red meat and 13.7 ± 0.01% of total poultry reported were processed. Prevalence of processed poultry intake increased from 9.5% (95% CI: 8.9, 10.1%) in 2007–2010 to 11.3% (95% CI: 10.2, 12.4%) in 2015–2018 ($P < 0.0001$), but mean intake amount did not change. Prevalence of processed red meat intake did not change over time, but mean intake decreased from 0.8 ± 0.03 ounce-equivalents in 2007–2010 to 0.7 ± 0.02 ounce-equivalents ($P = 0.0058$) in 2015–2018.

Conclusions: The Processed Meat Categories SAS program is a tool available for researchers to standardize estimates of processed meat subtypes for future dietary patterns research. Intake of total processed meat did not change in the United States, but intake amount of processed red meat decreased and the prevalence of processed poultry consumers increased. *J Nutr* 2022;152:190–199.

Keywords: US population, cured meat, nutrition surveillance, food groups, usual intake, dietary patterns, food pattern modeling

Introduction

The 2020–2025 Dietary Guidelines for Americans (DGA) recommend eating patterns that limit red and processed meat and also recommend that meats consumed should be lean and in fresh, frozen, or canned forms rather than processed (1). These recommendations are based on associations between dietary patterns high in red and processed meat and increased chronic disease risk (2), including cancer (3). Associated disease risk is likely influenced by the type (e.g., turkey), form (e.g., lean), processing (e.g., cured), and cooking methods (e.g., grilled) of meat (4). Yet, there is heterogeneity in how researchers define meats and subsequently assess meat and chronic disease risk (5). A systematic review of meat reporting practices showed that researchers estimate intakes of broad meat categories and do not include adequate descriptions of the foods that constitute those broad categories in ~20% of articles (5). For example, "red and processed meat" intake is commonly assessed (6, 7), which includes combinations of unprocessed red meat, processed red meat, and processed poultry (5). There are notable variations in nutrient and nonnutrient profiles of these meat categories (8), making interpretation of "red and processed meat" difficult. These findings are corroborated by 2015–2020 and 2020–2025 DGA Scientific Advisory Committees, which noted that a lack

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of standardized meat terminology across studies was a barrier to interpreting how meat influences chronic disease risk (6, 7).

Standardized methodology for establishing more granular meat intake categories is warranted for future research to further support food-based public health guidelines regarding processed meat intake. The United States Department of Agriculture (USDA)'s Food Patterns Equivalents Database (FPED) provides a resource for researchers to convert foods and beverages consumed in the United States into standardized food groups used to model the DGA recommended eating patterns (9). There are FPED groups for unprocessed red meat, unprocessed poultry, and processed meat. More recent trends of estimating unprocessed red meat intake independent of processed meat align with these FPED groups (10, 11). Yet, the FPED does not disaggregate processed meat further into processed red meat and processed poultry. Consequently, there is a paucity of research assessing intakes and associated disease risk of these more granular processed meat subtypes (12). It is important to understand potential differences in intake patterns of processed red meat and processed poultry due to consistent and strong associations observed between higher total processed meat intake and increased chronic disease risk, including cardiometabolic diseases (10, 11) and some types of cancer (3). Therefore, the objectives of this analysis were to *1*) create a standardized method of disaggregating processed meat into processed red meat and processed poultry using the FPED database and *2*) apply this new method to describe processed red meat and processed poultry intake patterns and trends over time among the US population aged ≥2 y.

Methods

Study design

We used data from the cross-sectional NHANES (National Health and Nutrition Examination Survey) conducted by the US Centers for Disease Control and Prevention (CDC)'s National Center for Health Statistics (NCHS). NHANES uses a multistage, complex, probability sampling approach to collect dietary intake data from a nationally representative sample of the civilian noninstitutionalized US population every 2 y since 1999. Survey sample design and weighting procedures are described elsewhere (13). Participants are recruited for a household interview and a physical examination conducted in NHANES mobile examination centers (MECs). For this analysis, we used the 2007–2008 to 2017–2018 NHANES data cycles.

Ethics

The NCHS Research Ethics Review Board approves all protocols for NHANES. Participants aged ≥18 y provide written consent, and consent is provided by a parent or guardian for those aged <18 y plus documented assent for those aged 7–17 y (14, 15).

Demographic characteristics

Self-reported demographic data are collected during the in-home interview portion of NHANES (16, 17). Demographic variables used in this analysis include age, gender (male and female), race and Hispanic origin (non-Hispanic white, non-Hispanic black, non-Hispanic Asian, and Hispanic), family income to poverty ratio (PIR; ≤130% or >130%, which is the cutoff for the Supplemental Nutrition Assistance Program), self-education attainment for participants aged ≥20 y, and head of household education attainment for those aged ≤19 y (high school or less, and more than high school).

Dietary intake assessment

The self-reported dietary data are collected by NCHS and the USDA in a joint survey effort referred to as What We Eat in America (WWEIA), NHANES (18). Trained interviewers at the MECs use the computer-assisted USDA Automated Multiple-Pass Method (19) for unannounced dietary recalls to ask participants what foods, beverages, and dietary supplements they consumed the prior day. A second unannounced recall was completed 3–10 d later via phone on a subsample of participants. Participants aged ≥12 y completed the dietary recall on their own, those aged 6–11 y were assisted by a proxy, and proxies reported intakes for those aged ≤5 y.

Each food and beverage reported by participants is linked to the USDA's Food and Nutrient Database for Dietary Studies (FNDDS) (20). Each FNDDS food code is accompanied by descriptions, ingredients, gram weights, and nutrient and energy values. The FNDDS food codes link to the FPED, which disaggregates each food code into ounce-equivalents (oz-eq), cup-equivalents, teaspoon-equivalents, or grams of 37 distinct food pattern components used to model the DGA recommended eating patterns, starting from the 2005–2006 NHANES data cycle (21, 22). The FNDDS food codes are also categorized into ∼15 WWEIA food categories and 150 subcategories that group food codes "as consumed" in the American diet (e.g., pizza or burgers) starting from the 2007–2008 cycle of NHANES (23).

Dietary behavioral characteristics

Self-reported information about diet behaviors is collected during the in-home interview via the Diet Behavior and Nutrition Questionnaire (24, 25). Questionnaire items included in this analysis were reported number of times food eaten away from the home in the prior 7 d (never, 1–3 times, ≥3 times), number of times fast food eaten in the prior 7 d (never, 1–3 times, ≥3 times), whether participants had heard of MyPlate (for those aged ≥16 y only; yes, no), and self-rated diet quality (for those aged ≥16 y only; very good to excellent, good, fair to poor). Self-rated health quality (very good to excellent, good, fair to poor) was also used and was reported in the Hospital Utilization & Access to Care questionnaire (26, 27).

Processed red meat and processed poultry variable creation

Definitions of meat terminology used.

The FPED defines cured meat as "frankfurters, sausages, and luncheon meats that are made from beef, pork, or poultry," based on regulations from the FDA (**Supplemental Table 1**). Hereafter, the "cured meat" FPED category, which includes most meats that undergo further processing consumed in the United States, is referred to as "processed meat" to be consistent with terminology used in prior scientific literature and public health guidelines. According to FPED, "meat" (i.e., red meat) is defined as "beef, veal, pork, lamb, and game meat; excludes organ meat and cured meat," and poultry is defined as "chicken, turkey, Cornish hens, duck, goose, quail, and pheasant (game birds); excludes organ meat and cured meat" (21, 22). In FPED, gram weight of solid fats present in meat >2.63 g is counted toward the solid fat FPED gram weight rather than processed meat FPED gram weight (21, 22). Therefore, all processed meats and other meat types discussed

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Supplemental Tables 1–6 and Supplemental Figures 1–9 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/jn/.
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Abbreviations used: AICR, American Institute for Cancer Research; BRR, balanced repeated replication; DGA, Dietary Guidelines for Americans; FNDDS, Food and Nutrient Database for Dietary Studies; FPED, Food Patterns Equivalents Database; IARC, International Agency for Research on Cancer; MEC, mobile examination center; NCHS, National Center for Health Statistics; NCI, National Cancer Institute; oz-eq, ounce-equivalent; PIR, family income to poverty ratio; WWEIA, What We Eat in America.

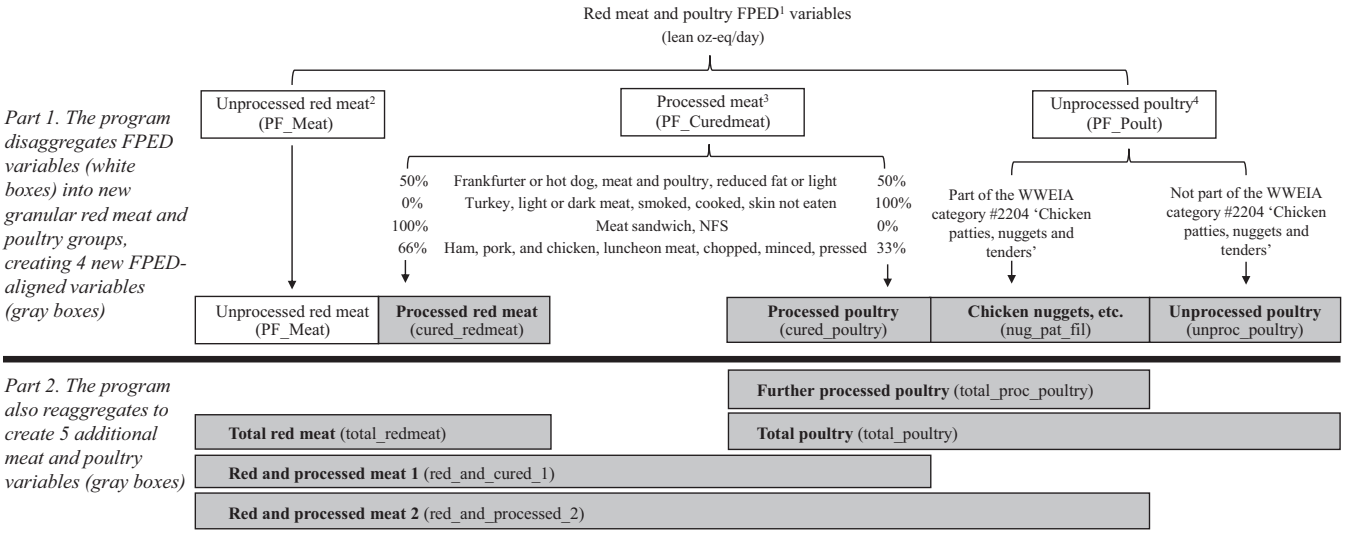

FIGURE 1 The process of creating new FPED-aligned meat variables using the National Cancer Institute's Processed Meat Categories SAS program. The text in parentheses indicates the variable names in the SAS program. This SAS program is available for researchers via the US National Cancer Institute at https://epi.grants.cancer.gov/ProcessedMeatCategories; it is described in more detail in Supplemental Table 2. Variables in the gray boxes are created by the Processed Meat Categories SAS program, and variables in the white boxes are in the FPED database. [1]The FPED is available at https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/fped-overview/.; [2]Beef, veal, pork, lamb, and game meat; excludes organ meat and processed meat. [3]Frankfurters, sausages, corned beef, processed ham, and luncheon meat that are made from beef, pork, or poultry. The FPED database uses the term "cured" instead of "processed"; see Methods and Supplemental Table 1 for more details. [4]Chicken, turkey, Cornish hens, duck, goose, quail, and pheasant (game birds); excludes organ meat and processed meat. FPED, Food Patterns Equivalents Database; NFS, Not further specified; PF, protein foods; WWEIA, What We Eat in America.

throughout this article should be interpreted as *lean* meat ounce-equivalents, but "lean" may not be repeated each time.

Manual coding of processed red meat and processed poultry.

We combined 2007–2008 to 2017–2018 NHANES data cycles because FNDDS food codes in these cycles are linked to the FPED and WWEIA food categories. We manually identified foods that contained a "cured meat" FPED component (n = 783 out of 10,813 total foods) using the FPED files that provide the serving equivalents per 100 g of FNDDS food codes (i.e., not yet including participant-level consumption data) (28). Two researchers independently disaggregated the processed meat FPED component of each food code into processed red meat and processed poultry using food code descriptions, additional descriptions, and ingredients lists available in FNDDS. Manual codes were crosschecked and discussed between researchers until consensus. The SAS program was developed to mimic the manual coding; therefore, the detailed decisions of disaggregating processed meat into processed red meat and processed poultry are described in the next section.

The Processed Meat Categories SAS program.

An automated SAS program, called Processed Meat Categories, was created to mimic the process of the manual coding to standardize the disaggregation of processed meat into processed red meat and processed poultry for reproducibility purposes of future research. Within each WWEIA food category, a series of "if/then do" statements were used to text-mine main food code descriptions, additional descriptions, and ingredients lists (mainly for mixed dishes only) using terms such as "poultry," "turkey," and "chicken" to identify processed poultry and "meat," "beef," or "pork" to identify processed red meat. If 1 red meat and 1 poultry component were identified, then the gram weight of processed meat was divided into 50% processed red meat/50% processed poultry. If 2 red meat and 1 poultry components were identified, then the gram weight of processed meat was divided into 66% processed red meat/33% processed poultry, etc. See **Figure 1** for examples. Some WWEIA categories (e.g., pizza, eggs and omelets) have processed red meat listed for all included food codes in FNDDS, and most processed meat in mixed dishes was denoted as bacon or ham. Based on this information, the entirety of these WWEIA categories were defaulted to processed red meat in our method, to best match FNDDS. Poultry ingredients are sometimes listed to obtain a nutrient profile that meets solid fat FPED requirements for lean processed meat, even if the food code is described as processed red meat. Therefore, our SAS program text-mining relied mainly on descriptions and additional descriptions and used ingredient lists for mixed dishes only to reduce misclassification of processed red meat as processed poultry. Pearson correlation and concordance correlations were calculated to compare results from the SAS program to manual coding using SAS version 9.4 (SAS Institute).

This SAS program is available for researchers via the US National Cancer Institute (NCI) at https://epi.grants.cancer.gov/ProcessedMeatCategories. A detailed description of what other meat-related variables are created by the SAS program is available in Figure 1 and **Supplemental Table 2**.

Sensitivity analyses in Processed Meat Categories SAS program development.

Processed red meat is the default for our program—that is, the program defaults to assigning the gram weight of processed meat to 100% processed red meat and 0% processed poultry if the program does not detect any of the specified terms or combinations of terms. This is the default because of the low frequency of specified processed poultry products in FNDDS from the top 10 processed meat–containing WWEIA food categories reported by participants in 2007–2008 through 2017–2018 (**Supplemental Table 3**). By defaulting all unspecified processed meat–containing food codes to processed red meat, we are confident in the direction of potential bias introduced by the method—that is, that processed red meat could be overestimated and processed poultry could be underestimated. In an attempt to quantify this overestimation, we conducted sensitivity analyses to compare how different default percentages would influence mean intake estimates. In addition, chicken nuggets or patties are not included in

the processed meat FPED but are considered to be further processed by some definitions (29). Therefore, we conducted an additional sensitivity analysis by comparing means of processed poultry with and without the poultry oz-eq from the WWEIA category 2204, which is "chicken patties, nuggets and tenders."

Analytical sample

The analytical sample used for this analysis included participants aged ≥2 y who participated in the MEC examination of the 2007–2008 to 2017–2018 NHANES cycles. Single survey cycles from 2007–2008 through 2017–2018 ($n = 55{,}735$) were used to assess intake trends over time, and data from 2015–2016 ($n = 9282$) and 2017–2018 ($n = 8663$) were combined for all other analyses. Participants were excluded if their dietary recall was deemed unreliable (2007–2018: $n = 7127$; 2015–2018: $n = 2907$) by NHANES data standards (30). This resulted in a final analytical sample of 48,608 participants for the trends analyses and 15,038 for the remaining analyses. Data for 84.4% of participants with a reliable second day of dietary data were used in statistical modeling of usual intakes. Participants were excluded from stratified analyses if data were missing for the stratified covariate of interest; adjusted sample sizes are noted throughout results. Unweighted examination response rates for participants of all ages were 75.4% in 2007–2008, 77.3% in 2009–2010, 69.5% in 2011–2012, 68.5% in 2013–2014, 58.7% in 2015–2016, and 48.8% in 2017–2018 (31). Weighting procedures by NCHS account for changes in response rates across cycles (32).

Statistical analysis

We used SAS version 9.4 and SAS-callable SUDAAN (release 11.0.3; Research Triangle Institute) survey commands to account for the complex survey design of NHANES. All analyses were weighted using day 1 dietary intake sample weights to account for oversampling, nonresponse, and post-stratification. All estimates were deemed reliable according to the NCHS data standards (33, 34), unless otherwise noted. We did not adjust for energy intake for ease of comparison to population-based FPED intake estimates available for each NHANES cycle via the USDA (9).

Prevalence of processed meat intake by population characteristics.

We combined 2015–2016 and 2017–2018 NHANES cycles and used proc descript in SUDAAN to estimate prevalence of intake (i.e., the percentage of the population who reported consumption) among the total population aged ≥2 y. Prevalence analyses were also stratified by demographic and behavioral characteristics, as described previously, to identify potential sociodemographic and behavioral characteristics associated with processed red meat and processed poultry. Pairwise comparisons within each stratum were conducted via proc surveyreg in SAS and Bonferroni adjusted for multiple comparisons within each stratum ($P < 0.05$).

Trends in prevalence and mean intake of processed meat over time.

Trends of prevalence (i.e., the percentage of the population who reported consumption) and mean intake (i.e., the amount consumed in lean oz-eq per day) were assessed over time from 2007–2008 to 2017–2018 for all participants aged ≥2 y, as well as stratified by gender and age (aged 2–18 y and ≥19 y). The day 1 dietary recall data were used and 2 NHANES cycles were combined for each time point to reduce random fluctuations in trends. Estimates were calculated via proc descript in SUDAAN, and trends over time were assessed via proc surveyreg in SAS by modeling time as an ordinal variable. Prevalence estimates are presented as percentage of total population and 95% CIs, calculated via the Clopper–Pearson method (33). Mean intake estimates are presented as mean oz-eq/per day ± SEM calculated via Taylor series linearization.

Usual intake distribution of processed meat.

We used the NCI usual intake method to estimate usual intake distributions of total processed meat, processed red meat, and processed poultry using NHANES 2015–2018 (35, 36). This method incorporates the second day of dietary recall data to adjust for random measurement error. We chose the 2-part model (i.e., for episodic food consumption) because >10% of the sample reported not consuming the foods of interest (37). There was no FFQ in these cycles of NHANES to confirm nonconsumers, so this model assigns half of the minimum intake value to all participants who report zero intake (i.e., nonconsumers on that day). Integerized balanced repeated replication (BRR) weights were used to account for the day of the week that the 24-h recall was conducted, differential weighting for subpopulations, and the multistage complex sampling design of NHANES (36). We calculated 32 BRR weights by all 60 post-stratification combinations of age, gender, and race/ethnicity consistent with the NHANES sampling methods, and we used 0.3 for the Fay method, which correlates with a perturbation factor of 70% (38). Estimates were adjusted for age, gender, and race/Hispanic origin, and results are presented for all participants aged ≥2 y, males aged 2–18 y, females aged 2–18 y, males aged ≥19 y, and females aged ≥19 y. We did not further stratify these results by race and Hispanic origin due to lack of differences in intake amounts of other meat types in prior cycles of NHANES noted elsewhere (39, 40).

Food sources of processed meat.

We used the weighted population proportion method (41) in proc surveymeans (42) to estimate the percentage of total processed meat that was processed red meat compared with processed poultry, the percentage of total red meat that was processed compared with unprocessed, and the percentage of total poultry that was processed compared with unprocessed. We then identified the top food sources by percentage of total processed meat, processed red meat, and processed poultry using the WWEIA food categories (22). We created meat-specific survey weights by multiplying intake of each meat type by day 1 dietary intake survey weights. Reported results include food categories that contributed ≥3% of each meat type.

Results

Processed Meat Categories SAS program

Of the 783 food codes that contained processed meat from 2007–2008 to 2017–2018, 666 were identified as processed red meat only, 39 were identified as processed poultry only, and 78 were identified as a combination of both processed red meat and processed poultry. Pearson correlation and concordance correlations between the manual code and Processed Meat Categories SAS program were 0.98 for processed red meat and 0.95 for processed poultry (**Supplemental Figure 1**). Most discrepancies occurred for food codes in which descriptions did not match corresponding ingredients list (**Supplemental Table 4**)—that is, the food code was described as containing processed meat, but the ingredient listed was processed poultry to meet the nutrient profile requirements of a lean meat. Our sensitivity analyses revealed that the default setting for food codes with inadequate descriptive information to decipher designation (100% of processed meat is designated as processed red meat and 0% as poultry) may overestimate processed red meat intake by up to 12% (**Supplemental Table 5**). Our sensitivity analyses also revealed that inclusion of chicken patties, nuggets, and tenders as processed poultry products (29) can meaningfully influence intake estimates of processed poultry, particularly for those aged <19 y (0.2 ± 0.02 compared with 0.5 ± 0.03 oz-eq; **Supplemental Table 6**).

Prevalence of processed meat intake by population characteristics

Using 2015–2018 NHANES data, 46.8% (95% CI: 45.3, 48.2%) of the US population aged ≥2 y reported consuming any processed meat, 42.5% (95% CI: 41.0, 43.9%) reported

TABLE 1 Prevalence of those reporting consumption of total processed meat, processed red meat, and processed poultry among the US population aged ≥2 y, stratified by sociodemographic and behavioral characteristics[1]

		Total processed meat		Processed red meat		Processed poultry	
Characteristic	*n*	Prevalence	95% CI	Prevalence	95% CI	Prevalence	95% CI
Sex							
Male	7358	51[a]	(49.3, 52.7)	47[a]	(45.1, 48.8)	12[a]	(11.0, 13.9)
Female	7680	43[b]	(40.9, 44.6)	38[b]	(36.5, 39.9)	10[b]	(9.0, 11.5)
Ethnicity and race							
Non-Hispanic white	5033	50[a]	(47.8, 51.2)	45[a]	(43.3, 46.3)	12[a]	(11.0, 14.1)
Hispanic	4165	44[b]	(41.3, 47.1)	41[a]	(38.5, 44.0)	8[b]	(6.3, 9.2)
Non-Hispanic black	3373	48[ab]	(44.9, 50.9)	43[a]	(39.7, 46.1)	13[a]	(11.5, 15)
Non-Hispanic Asian	1610	24[c]	(20.3, 27.2)	22[b]	(18.4, 24.8)	4[c]	(3.1, 6.0)
Education level							
High school or less	5964	47	(45.3, 48.8)	44[a]	(41.7, 45.5)	10[a]	(8.9, 11.2)
More than high school	6038	46	(43.2, 48.1)	41[b]	(38.6, 42.8)	12[b]	(10.6, 13.6)
PIR,[2] %							
<130	4557	46	(42.9, 48.7)	42	(39.2, 45.2)	10	(8.4, 11.4)
≥130	8982	48	(45.9, 49.3)	43	(41.6, 44.5)	12	(10.3, 13.2)
Meals away from home in past 7 d							
0	3301	43*	(39.4, 45)	37*	(34.1, 39.5)	11	(8.2, 13.7)
1–3	5577	46	(43.1, 47.9)	42	(39.1, 44.1)	11	(9.5, 12.1)
≥3	6099	50	(47.0, 51.9)	45	(42.9, 47.6)	12	(10.5, 13.3)
Fast food meals in past 7 d							
0	2730	43*	(39.5, 46)	39*	(35.5, 42.4)	10*	(8.1, 11.0)
1–3	5859	49	(46.3, 50.6)	44	(42.2, 46.1)	12	(10.6, 13.9)
≥3	3079	51	(48.3, 54.3)	47	(44.4, 50.5)	12	(10.2, 13.3)
Heard of MyPlate[3]							
Yes	2336	46	(42.2, 48.8)	41	(37.8, 44.1)	11	(9.1, 13.3)
No	8483	46	(44.5, 47.8)	42	(40.7, 43.8)	11	(9.9, 12.0)
Self-rated diet quality[3]							
Very good to excellent	2882	41*	(37.7, 44.0)	36*	(33.3, 39.6)	10	(8.1, 12.0)
Good	4301	47	(45.3, 49.6)	43	(40.4, 44.8)	12	(10.5, 14.1)
Fair to poor	3659	49	(47.0, 51.0)	46	(44.2, 48.1)	10	(8.7, 11.6)
Self-rated health quality							
Very good to excellent	7324	47	(44.3, 49)	42	(39.3, 43.8)	12	(10.6, 13.5)
Good	4887	48	(45.3, 49.9)	44	(41.6, 46.3)	11	(9.3, 12.5)
Fair to poor	2814	45	(43.0, 47.8)	43	(40.0, 45.4)	10	(8.2, 11.2)

[1]Different letters indicate different estimates ($P < 0.05$, Bonferroni corrected) between levels of each characteristic within processed meat subtype (e.g., prevalence of total processed meat is different between males and females but not different between the 2 levels of educational attainment). Asterisks indicate a linear trend across levels of the characteristic within processed meat subtype ($P < 0.05$). PIR, poverty income ratio. Source: CDC/National Center for Health Statistics, NHANES 2015–2018, day 1 dietary recall data.

[2]The ratio of household income to the federal poverty threshold.

[3]Heard of MyPlate and self-rated diet quality were only asked for those aged ≥16 y.

consuming processed red meat, and 11.3% (95% CI: 10.2, 12.4%) reported consuming processed poultry (Table 1). Intake prevalence of all processed meat categories was higher for males than for females [8.2 ± 0.98% higher for total processed meat ($P < 0.0001$), 8.8 ± 1.04% higher for processed red meat ($P < 0.0001$), and 2.3 ± 0.76% higher for processed poultry ($P = 0.0062$)]. Approximately 50% fewer non-Hispanic Asians compared with other race and Hispanic origin groups reported consuming total processed meat, processed red meat, and processed poultry. The intake prevalence of total processed meat was higher for non-Hispanic whites than Hispanics, and the prevalence of processed poultry intake was higher for non-Hispanic whites and non-Hispanic blacks than Hispanics. No differences were observed between non-Hispanic whites, non-Hispanic blacks, and Hispanics in the prevalence of processed red meat intake. Prevalence of total processed meat intake did not differ by education level ($P = 0.36$), but prevalence of processed red meat intake was 3.0 ± 1.37% ($P = 0.0412$) higher and prevalence of processed poultry intake was 2.0 ± 0.78% ($P = 0.0143$) lower for those with less compared with more education. Intake prevalence did not differ based on PIR. Prevalence of total processed meat ($P = 0.0016$) and processed red meat ($P = 0.0002$), but not processed poultry ($P = 0.46$), was higher with higher frequency of meals away from home. Prevalence of total processed meat, processed red meat, and processed poultry was higher with higher frequency of fast food meals ($P < 0.05$). Prevalence of total processed meat ($P = 0.0001$), processed red meat ($P < 0.0001$), but not processed poultry ($P = 0.07$), was lower for those with higher self-rated diet quality but not by awareness of MyPlate or self-rated health quality.

Trends in prevalence and mean intake of processed meat over time

Prevalence and mean intake of total processed meat did not change from 2007–2010 to 2015–2018 for the total population aged ≥2 y (Figure 2). Prevalence of processed poultry intake increased from 9.5% (95% CI: 8.9, 10.1%) in 2007–2010 to

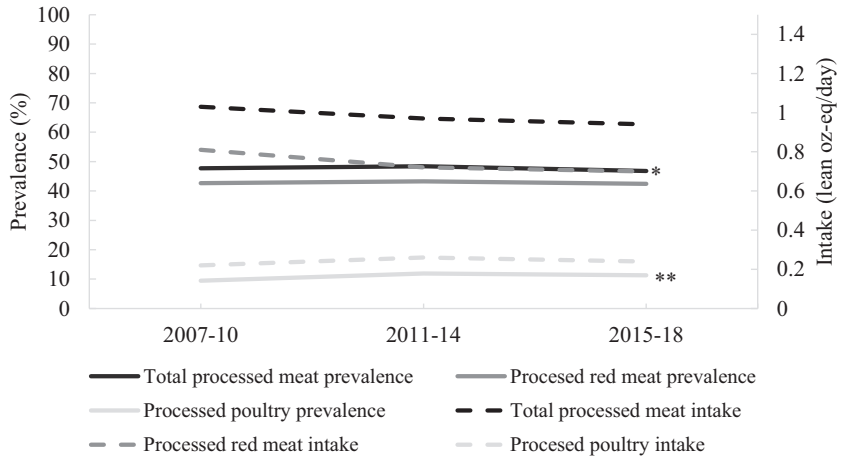

FIGURE 2 Prevalence of consumption (solid line) and mean intake (dashed line) of total processed meat, processed red meat, and processed poultry of the US population aged ≥2 y from 2007–2008 to 2017–2018. *$P < 0.05$, **$P < 0.01$. Source: CDC/National Center for Health Statistics, NHANES 2007–2008 to 2017–2018, day 1 dietary recall data.

11.3% (95% CI: 10.2, 12.4%) in 2015–2018 ($P < 0.0001$), but mean intake did not change. The prevalence of processed red meat intake did not change over time, but mean intake decreased from 0.8 ± 0.03 oz-eq in 2007–2010 to 0.7 ± 0.02 oz-eq in 2015–2018 ($P = 0.0058$). When stratified by age, an increase in prevalence of only processed poultry intake was observed for both males (**Supplemental Figure 2**; $P = 0.0028$) and females (**Supplemental Figure 3**; $P = 0.0322$) aged 2–18 y. Among males aged ≥19 y, prevalence of intake did not change, but mean intake of total processed meat decreased (from 1.4 ± 0.06 oz-eq in 2007–2010 to 1.2 ± 0.05 oz-eq in 2015–2018; $P = 0.0271$) and mean intake of processed red meat decreased (from 1.2 ± 0.05 oz-eq in 2007–2010 to 1.0 ± 0.04 oz-eq in 2015–2018; $P = 0.0030$; **Supplemental Figure 4**). Prevalence of processed poultry intake increased in males ≥19 y (from 9.5 ± 0.42% in 2007–2010 to 12.2 ± 0.76% in 2015–2018; $P = 0.0002$), whereas intake did not change ($P = 0.19$). There were no changes in prevalence or intake amounts for females aged ≥19 y (**Supplemental Figure 5**).

Usual intake distribution of processed meat

Intake in the 95th percentile of the population aged ≥2 y was 2.2 ± 0.07 oz-eq/d for total processed meat, 1.7 ± 0.06 oz-eq/d for processed red meat, and 0.8 ± 0.06 oz-eq/d for processed poultry (Figure 3, Supplemental Table 6). Intake in the 95th percentile of males aged 2–18 y was 1.8 ± 0.16 oz-eq/d for total processed meat, 1.5 ± 0.13 oz-eq/d for processed red meat, and 0.7 ± 0.07 oz-eq/d for processed poultry (**Supplemental Figure 6**). Intake in the 95th percentile of females aged 2–18 y was 1.4 ± 0.12 oz-eq/d for total processed meat, 1.1 ± 0.08 oz-eq/d for processed red meat, and 0.6 ± 0.07 oz-eq/d for processed poultry (**Supplemental Figure 7**). Intake in the 95th percentile of males aged ≥19 y was 2.7 ± 0.13 oz-eq/d for total processed meat, 2.2 ± 0.10 oz-eq/d for processed red meat, and 1.0 ± 0.11 oz-eq/d for processed poultry (**Supplemental Figure 8**). Intake in the 95th percentile of females aged ≥19 y was 1.6 ± 0.10 oz-eq/d for total processed meat, 1.1 ± 0.08 oz-eq/d for processed red meat, and 0.7 ± 0.09 oz-eq/d for processed poultry (**Supplemental Figure 9**).

Food sources of processed meat

For the population aged ≥2 y, processed red meat and processed poultry comprised ~25% of all red meat and poultry reported (Figure 4). The majority of total processed meat intake was processed red meat compared with processed poultry. Most of total red meat was unprocessed compared with processed. Similarly, most of total poultry was unprocessed compared with processed. The largest food source contributor of total processed

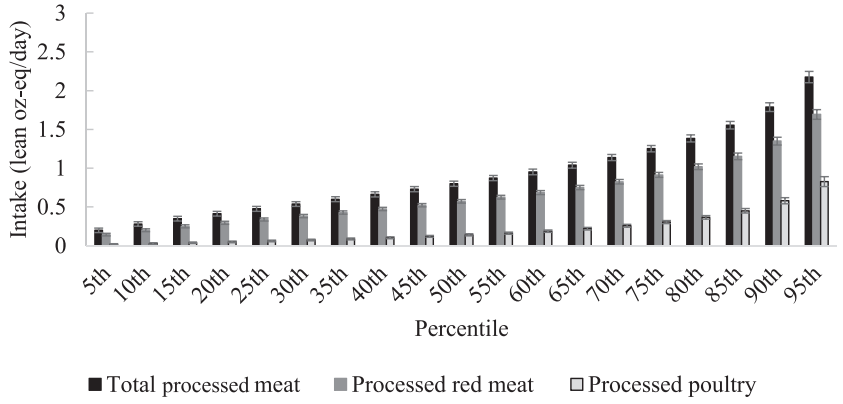

FIGURE 3 Distribution of total processed meat, processed red meat, and processed poultry intake of the US population aged ≥2 y. Estimated via the National Cancer Institute's usual intake 2-compartment model (35) using day 1 and day 2 dietary recall data to estimate usual intake. Source: CDC/National Center for Health Statistics, NHANES 2015–2018.

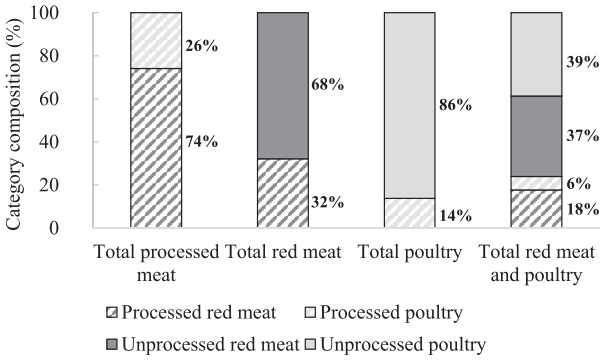

FIGURE 4 Composition of total processed meat, total red meat, total poultry, and total meat and poultry intake of the US population aged ≥2 y. Data are shown as weighted population proportion × 100% (41). Source: CDC/National Center for Health Statistics, NHANES 2015–2018, day 1 dietary recall data.

meat was from cold cuts (51.6 ± 1.7%), 14.3 ± 1.3% from sausages, 9.8 ± 0.7% from frankfurter sandwiches, 4.5 ± 0.3% from pizza, and 4.2 ± 0.4% from bacon. Similarly, approximately half of processed red meat (46.2 ± 2.0%) was from cold cuts, 14.5 ± 1.5% from sausages, 10.0 ± 0.65% from frankfurter sandwiches, 6.0 ± 0.4% from pizza, 4.6 ± 0.34% from bacon, and 4.1 ± 0.3% from egg/breakfast sandwiches. For processed poultry, 67.1 ± 2.2% was from cold cuts, 13.5 ± 1.3% from sausages, and 9.4 ± 1.5% from frankfurter sandwiches.

Discussion

The NCI's Processed Meat Categories SAS program provides a novel, transparent, and standardized method of estimating processed red meat and processed poultry intake using a nationally representative US database. By implementing this methodology, we found that ∼70% of total processed meat consumed in the United States is processed red meat, and the remaining ∼30% is processed poultry. In addition, ∼25% of all red meat and poultry reported is processed. The prevalence of processed red meat intake did not change over time (∼50% of the US population aged ≥2 y), but the amount reported decreased, particularly for males. This may reflect that processed red meat consumers are consuming smaller portions of processed red meat. The prevalence of processed poultry intake increased over time, except for adult females, whose processed meat intake behaviors did not change. These trends are supported by decreasing unprocessed red meat and increasing unprocessed poultry self-reported intake in the United States (39, 40), as well as trends in the US food supply (43). Prevalence of processed red meat and processed poultry intake was higher with higher frequency of meals away from home, higher frequency of fast food, and lower self-rated diet quality, which are common features of high meat-containing Western-style eating behaviors (7). Dissemination of the Processed Meat Categories SAS program will encourage future investigation on how granular processed meat subtypes influence diet quality and chronic disease risk to inform future dietary guidance.

Our Processed Meat Categories SAS program can be used in nutrition monitoring and surveillance, food pattern modeling, risk assessment, or policy analyses. In addition to NHANES, other data sets that link to the FNDDS database can use our SAS program to estimate lean meat oz-eq of processed red meat, processed poultry, and several other meat variables (Supplemental Table 2). Therefore, it is important that potential utility and limitations of this method are clear. Our code uses the FPED, in which gram weight of solid fats present in meat >2.63 g is counted toward solid fat FPED weight rather than processed meat FPED weight (27). Therefore, the unit of the variables from this program is *lean* meat oz-eq. Also, the ingredient lists for FNDDS meat-containing food codes are created to obtain a nutrient profile that meets these lean meat specifications. Most poultry products are leaner than red meat and therefore are occasionally listed as an ingredient even if a processed red meat was indicated in the food code description (Supplemental Table 4). Our program operationalizes mostly food code descriptions rather than ingredient lists (except for mixed dishes), but there is still potential for misclassification. We defaulted to processed red meat when processed meat type was ambiguous, which potentially overestimates processed red meat and underestimates processed poultry by 10–15% based on our sensitivity analyses (Supplemental Table 5). Last, processed red meat and processed poultry components of food codes were assumed to be of equal weight due to lack of needed detail to decipher otherwise in FNDDS. Overall, our SAS program provides a standardized method for researchers to assess processed meat subtypes and additional meat groups consumed by the US population for future meat or dietary pattern research.

Public health messaging about processed meat intake and chronic disease risk has evolved during the time span that our trend analysis covers. In 2015, the International Agency for Cancer Research (IARC) deemed processed meat as a group 1 carcinogen (44). In 2018, the American Institute for Cancer Research (AICR) recommended little or no processed meat intake, primarily for the prevention of colorectal cancer risk in adults (45). The 2020–2025 DGA state that meat and poultry products should be lean and from fresh, frozen, or canned rather than processed sources (1). The goal of these public health organizations is to reduce or eliminate processed meat intake, and a quantified safe allotment is not provided. For research and evaluation purposes, AICR's recommendation equates to <0.75 oz/d of total processed meat intake for adults (46). Our results show that the median lean processed meat intake of adults in the United States was >1 oz-eq in 2015–2018 NHANES cycles. However, true intakes are likely higher because processed meats can be high in solid fats, and FPED includes only the lean meat portion. Our results also help identify subpopulations to target in continued future public health efforts to reduce processed meat intake—that is, individuals who are Hispanic, non-Hispanic black or white, and who consume most meals away from home. It will be important to continue to monitor trends in processed meat intake in these subgroups as awareness of these guidelines in the general public increases.

The IARC, AICR, and DGA recommend limiting processed meat intake, and they do not have specific recommendations about processed meat subtypes (1, 44, 45). Our results show that total processed meat intake was relatively unchanged during the past decade, and composition shifted slightly from processed red meat to processed poultry. An analysis of the Multiethnic Cohort Study suggests that risk for diabetes associated with processed red meat is almost double that of processed poultry [adjusted HR and 95% CI for processed red meat: 1.57 (1.42, 1.75); adjusted HR and 95% CI for processed poultry: 1.30 (1.17, 1.44)] (12). High concentrations of sodium and nitrates are present in both processed red meat and processed

poultry, and processed red meat contains higher concentrations of heme iron and saturated fat (8). Sodium, nitrates, heme iron, and saturated fat are all proposed mechanisms of how processed meat intake is associated with increased risk for various chronic diseases (3, 47–50). Yet, research to further assess whether processed red meat affects chronic disease risk to a greater extent than processed poultry is lacking. Our Processed Meat Categories SAS program will support this type of future investigation by standardizing exposure assessments in observational studies, nationally representative intake estimates, and can aid in menu planning for controlled interventions.

Processed meat terminology and definitions vary across public health resources. For example, the FPED variable that we use in our SAS program is referred to as "cured meat" (described in Supplemental Table 1), which is inclusive of most processed meat sources typically consumed by the US population. Potential processed meats that are not classified by our SAS program vary by how processed meat is defined. For example, chicken nuggets and patties are considered further processed by the American Meat Science Association (29). In a sensitivity analysis, inclusion of chicken patties, nuggets, and tenders as processed poultry doubled processed poultry intake estimates in those aged <19 y. Another example is that marinated chicken breasts are considered processed according to prior DGA (6). We did not classify marinated chicken as processed poultry due to lack of consensus across agencies as well as lack of needed detail in FNDDS. Researchers should be cognizant of how to operationalize the Processed Meat Categories SAS program depending on what meat definitions they are utilizing. Further research is needed to quantitatively assess how variations in meat definitions may influence population-based intake estimates and associations with chronic disease risk.

Our intake estimates of processed red meat and processed poultry in the US population are strengthened by use of a standardized processed meat classification method using a nationally representative food database and US sample. Yet, this method relies on self-reported dietary intake data that have documented limitations (51, 52). The AMPM method used in NHANES is the gold standard for self-reported dietary assessment, but further validation is needed to determine how accurately participants can recall the needed degree of detail about meat type (e.g., whether the sausage on their pizza was pork, chicken, or a mix) or if additional and more targeted probes are required. Last, our program relies on FNDDS-specific food codes and accompanying information that may not be linkable to all dietary assessment methods (e.g., FFQs that use higher level food composites) or other dietary databases without further methodological development.

The Processed Meat Categories SAS program provides a transparent and standardized tool for researchers to estimate intakes of processed red meat, processed poultry, and a variety of other novel meat categories. We demonstrated application of this method to a nationally representative US sample and showed that most of the processed meat consumed in the United States is processed red meat and ~25% of all red meat and poultry intake is processed. Total intake of processed meat was relatively stable over time, but there was a shift from processed red meat to processed poultry during the past decade. Our Processed Meat Categories method allows for future investigation into how the nuances of animal-based protein sources may differentially impact diet quality, eating patterns, or chronic disease risk.

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Data Availability

Data are publicly available from the National Center for Health Statistics (https://www.cdc.gov/nchs/nhanes/index.htm). The Processed Meat Categories SAS code is publicly available from the National Cancer Institute (https://epi.grants.cancer.gov/ProcessedMeatCategories). Programming code for this analysis and summary data are available upon request from the corresponding author.

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