

## Methods and Findings on Diet and Lifestyle Used to Support Estimation of Radiation Doses from Radioactive Fallout from the Trinity Nuclear Test

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**Abstract**—The Trinity nuclear test was detonated in south-central New Mexico on 16 July 1945; in the early 2000s, the National Cancer Institute undertook a dose and cancer risk projection study of the possible health impacts of the test. In order to conduct a comprehensive dose assessment for the Trinity test, we collected diet and lifestyle data relevant to the populations living in New Mexico around the time of the test. This report describes the methodology developed to capture the data used to calculate radiation exposures and presents dietary and lifestyle data results for the main exposure pathways considered in the dose reconstruction. Individual interviews and focus groups were conducted in 2017 among older adults who had lived in the same New Mexico community during the 1940s or 1950s. Interview questions and guided group discussions focused on specific aspects of diet, water, type of housing, and time spent outdoors for different age groups. Thirteen focus groups and 11 individual interviews were conducted among Hispanic, White, and Native American participants. Extensive written notes and audio recordings aided in the coding of all responses used to derive ranges, prevalence, means, and standard deviations for each exposure variable for various age categories by region and ethnicity. Children aged 11–15 y in 1940s or 1950s from the rural plains had the highest milk intakes (993 mL d<sup>-1</sup>), and lowest intakes were among 11- to 15-y-olds in mountainous regions (191 mL d<sup>-1</sup>). Lactose intolerance rates were 7–71%, and prevalence was highest among Native

Americans. Meat was not commonly consumed in the summer in most communities, and if consumed, it was among those aged 11–15 y of age or older who had relatively small amounts of 100–200 g d<sup>-1</sup>. Most drinking and cooking water came from covered wells, and most homes were made of adobe, which provided more protection from external radiation than wooden structures. The use of multiple approaches to trigger memory and collect participant reports on diet and other factors from the distant past seemed effective. These data were summarized, and together with other information, these data have been used to estimate radiation doses for representative persons of all ages in the main ethnic groups residing in New Mexico at the time of the Trinity nuclear test.

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**Key words:** exposure, population; exposure, radiation; intake, radionuclide; internal dose

### INTRODUCTION

THE TRINITY nuclear device was the culmination of the Manhattan Project to develop the first atomic bomb. The device called Trinity was tested at the Alamogordo Bombing and Gunnery Range in south-central New Mexico on 16 July 1945. The communities near the Trinity test site were not given any notice or warning about the test since it was classified as top secret. To our knowledge, aside from a brief report by the US National Cancer Institute (NCI) to Congress in 2007, no research studies have been conducted to assess the health impact of the Trinity nuclear test on the people of New Mexico.

From 2016 to 2017, the NCI conducted a field study to inform a study to estimate cancer risk from Trinity already underway. In collaboration with the NCI radiation dosimetrists, a multidisciplinary team was assembled to collect data and derive estimates of lifestyle factors that could be applied to the dose assessment methods for the Trinity test. Information needed included dietary practices, sources of water, house construction materials, time spent outdoors in summer months, and other factors. It was necessary to obtain appropriate lifestyle and dietary input data for the

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populations in New Mexico, including the sizeable proportion of Hispanic/Latinos, as well as White and Native American tribal community members.<sup>8</sup> To fully represent the geographic and sociological diversity of New Mexico, information was needed for both urban and rural settings and different environment types (e.g., plains, mountains).

Five cancer endpoints are being studied (Cahoon et al. 2020): colon, lung, active (red) bone marrow, stomach, and thyroid. Generally, the major health risk associated with exposure to radioactive fallout is that of thyroid cancer resulting from internal exposures of the thyroid gland to radioiodine primarily through consumption of contaminated water, milk, other dairy products, and leafy vegetables. To a lesser degree, consumption of other food products (e.g., vegetables, fruits, and meats from animals that grazed on contaminated vegetation) could contribute to the radiation dose to human beings. In terms of radioiodine exposure, children are especially vulnerable because they often consume large amounts of dairy products and have small thyroid glands, which implies the energy from the radioactive decay will be concentrated in a smaller mass. Although there is existing information about the date and time of radiation fallout exposure for each community as derived from fallout maps (Beck et al. 2020; Bouville et al. 2020), the internal radiation exposure depends, to a large degree, on the consumption rate of contaminated food products, which generally varies by age. External radiation exposure depends on other factors, including the magnitude of the local deposition, time spent outdoors, and the type of construction materials for the home. In New Mexico, the predominant construction materials were adobe (earth mixed with water and an organic material such as straw) and wood during the time of the test.

From research in the field of nutritional epidemiology, it is better to inquire about the past diet than to use current diet as an estimate of a person's past diet (Willett 2013). Therefore, it is necessary to inquire about past diet around the time of the test. Based on similar methods and analyses as part of a dose reconstruction and epidemiological study of thyroid disease related to nuclear testing in Kazakhstan beginning in 1949 (Schwerin et al. 2010; Drozdovitch et al. 2011), focus groups with individuals who were living in New Mexico in the years close in time to the detonation appeared to be a useful research approach to address diet and other lifestyle factors. Details of the Kazakhstan study are described in the Discussion.

Data suggest that older adults benefit from group discussions of topics from the past. Focus group interviews have been shown to increase participant comfort when individuals are gathered into homogeneous groups (Kitzinger 1995; Krueger 2000; Lakshman et al. 2000), and focus groups with older adults generate a broader range of thoughts than

individual interviews (Kitzinger 1995). In terms of recollection of past events, groups were thought to have improved recollection compared to individual interviews.

Described in this paper are the methods and results of data collection as part of the NCI study to examine potential radiation exposures and related health risks across the state of New Mexico from the Trinity nuclear test. Accordingly, the objectives of this paper are to (1) describe the methodology developed to capture lifestyle data through focus groups and interviews in older adults who had lived in these communities in the 1940s and 1950s and (2) to present results obtained from the focus groups and interviews on consumption of a variety of foods as well as lifestyle parameters that can influence dose.

## MATERIALS AND METHODS

### Primary goals

The primary goal of the data collection phase of the NCI Trinity study was to acquire diet and lifestyle data that were relevant to all strata of the New Mexico population for which dose assessment was contemplated. The strata of the study population were defined to be all combinations of the primary attributes that might serve to differentiate New Mexico residents in terms of the doses likely to have been received. The basis of requiring data on each stratum is because data that differentiated population groups is needed to support a reasonably reliable estimation of radiation dose. The main attributes that appeared to possibly differentiate groups included ethnicity; gender; age (1–4 y, 5–10 y, 11–15 y, and 16+ y); general geographic location in the state (north/south); environment type (also called ecozone), which included plains, mountains, plains/mountains; and population density (urban and rural). In the analysis phase of the collected data from the field, data sets were derived for the purpose of dose reconstruction that covered, to the degree possible, the originally contemplated strata based on consideration for the quality of data and the similarity of data by region and ethnicity.

In preparation for the data collection phase, we conducted an extensive literature review to assess typical foods consumed and dietary patterns in New Mexico in the 1940s among Native Americans and Hispanic/Latino populations. The review was focused on five main food groups with relevance to human exposure to radioactive isotopes of elements that can be transferred via fallout-contaminated foods: (1) dairy, (2) meat and organs of large and small animals, (3) plants, (4) fruit, and (5) drinking water. After all potential sources of dietary contamination were reviewed and the list of foods was complete, we ranked the foods by three levels of potential exposure to human beings: high, moderate, and low. These rankings were based on the apparent frequency of consumption, whether an important pathway of radiation exposure might be involved, or if certain

<sup>8</sup>The findings in this paper do not apply to the Navajo Nation.

at-risk population groups, such as women and infants, differed in their consumption pattern. The key foods identified by this exercise were subsequently included in the data collection instruments so that information on the consumed amounts could be queried during focus-group meetings or individual interviews. Findings from the literature review and pilot interviews also indicated that the way of life in New Mexico did not change drastically between the 1940s and 1950s.

### Participant recruitment

Eligible participants were aged 70 y or older, had lived in their New Mexico community during the 1940s and/or 1950s, and were mentally competent to participate in the focus groups or individual interviews. Although many participants currently aged 70–80 y were too young in 1945 to recollect their lifestyles that year, they were asked to report on their typical behaviors in the 1940s and 1950s, which should adequately represent their behaviors in the time period of interest. Because dietary recalls and estimates of portion size are not reliable for those younger than 8 to 12 y at the time being recalled (Livingstone and Robson 2000; Livingstone et al. 2004), some of the younger participants were asked to report on activities in the 1950s that they could recall.

In consultation with the Albuquerque Area Southwest Tribal Epidemiology Center (AASTEC) and the Albuquerque Area Indian Health Board (AAIHB), we followed protocols for obtaining approval of the Southwest Tribal IRB, provided information to potentially interested Native American tribes, met with tribal leaders, and obtained Tribal Resolutions, which granted permission for the study of a specific tribal group. In addition, we worked with local Native American consultants and subject matter experts who facilitated contacts with the tribes. Local New Mexican communities, tribal leaders, and local Native American institutional review boards were consulted regarding appropriate recruitment methods, cultural or linguistic practices and needs, as well as providing suggestions of eligible and appropriate participants for focus groups or interviews.

For Hispanic and White groups, local academic collaborators contacted senior centers and community leaders to invite participation in the study and to schedule the focus groups. Advertisements were posted in local newspapers inviting possible respondents to join the study. Senior Centers representing relevant eco-regions in the state also conducted outreach to seniors they served and provided input on who in the community might be able to participate. In addition, flyers were posted in the Senior Centers to solicit volunteers. The most important criteria for eligibility were age and cognitive ability among potential respondents. Local academic partners and members of the study team conducted screening interviews with potential participants in the appropriate language to determine their eligibility to participate. The collaborators subsequently invited eligible

participants to attend a focus group or individual interview and provided details on the time, date, and location for the data collection. Senior centers' directors were instrumental in bringing in qualified elders and organizing the timing of the focus groups and individual interviews.

All willing individuals who met the inclusion criteria were invited to participate in the data collection. Pilot testing in 2014 with nine volunteers aged 70–103 y using the individual interview method demonstrated the willingness and ability of individuals to engage in recollection of the key information being queried. In the 2016–2017 field work, efforts were made to construct homogeneous focus groups according to ethnicity and region based on where participants reported living in the 1940s and 1950s. The NCI's Special Studies institutional review board (IRB) and the Southwest Tribal IRB approved the study.

### Focus group and interview procedures

One experienced individual (SIS) moderated all focus groups and co-facilitated all the logistics for the field work. The emphasis of the focus group questions was on dietary intakes of members of the family unit at all ages. Instruments developed for data collection were translated into Spanish, and the focus group moderator spoke in Spanish or English as needed. The moderator asked each Native American community for their preferred language, and most of these participants preferred speaking English, although an interpreter was available when needed. To aid with recollection of the time of year of the Trinity test and to incorporate seasonal changes in food intakes, respondents were queried about dietary intakes and activities in the summer and early autumn months. In addition, data collection was conducted from July to October so that seasonal foods would have been recently consumed.

Plates, bowls, glasses, and a baby bottle from the 1940s were placed on the table of the focus group to help respondents estimate serving sizes, while on the walls of the room in which the focus group was conducted, archival black and white photographs were displayed of activities from the 1940s. The bowls and cups had markings for different volumes to help gauge amounts. For the focus groups of Native Americans, some of the dishes on the tables were replaced with clay bowls and cooking pots common in their communities in the 1940s and 1950s. To facilitate discussions and provide context for questions, large charts on the walls showed different types of foods and the various age groups of interest (1–4 y, 5–10 y, 11–15 y, and 16+ y).

Each focus group participant was given a booklet showing a range of serving sizes as an additional aid for the estimation of the amounts of foods consumed. We developed the serving size booklet based largely on the Nutrition Assessment Shared Resource Serving Size Booklet used at the Fred Hutchinson Cancer Research Center (2000) for nutrition and epidemiologic studies. The main modification was

to limit the foods included to those of interest in the Trinity assessment. For each food group, the booklet displayed four color photographs of a sample food item on a standard-sized plate with utensils on the sides and a written indication of the portion size. The booklet also included one page with pictures and hints to help respondents estimate the servings of various foods; for example, the booklet explained that 1 cup of mashed potatoes was about the size of a fist. A drawing of a glass with delineations of 3, 6, 9, and 12 ounces was designed to assist with estimates of fluid intake.

Before each focus group discussion, the moderator and data collection team members greeted participants. The moderator paraphrased the consent form and then gave participants additional time to read and sign the consent to indicate their willingness to participate. Members of the study team worked with each participant to complete a form indicating family members that were living together in the same home with the participant during the 1940s and 1950s, such as parents, siblings, grandparents, and other extended family members. The individual interviews were for subjects who preferred one-on-one interviews rather than the group sessions. Individual interview respondents used a printed sample-serving-size color booklet to determine food serving amounts. The responses from the individual interviews addressed community level behaviors and some quantitative information about food amounts. Whenever appropriate, the focus group sessions would open and close with a prayer or blessing and sharing a meal, before or after the session, as is common practice in this region. Two note-takers who were members of the study team attended each focus group, and they identified each participant by number in their recorded notes.

The moderator began each session by asking all participants for permission to make an audio recording of the discussion and to use a Livescribe ballpoint smartpen (Livescribe, Inc., San Francisco, CA) with an embedded computer and digital audio recorder. There were no recordings made if a single participant objected, which resulted in three focus groups without audio recordings. Each participant then performed a card sorting exercise wherein 10 major food items (milk; cheese; meat from large, medium, and small animals; dried meats; fruits; leafy green vegetables; root vegetables; and grains) were put in order from highest to lowest frequency of consumption by their families in the 1940s and 1950s.

The moderator continued with open-ended questions about daily life at the time of the Trinity test and personal knowledge of the Trinity nuclear test. Next, the moderator asked questions about the following topics:

- How long women breastfed their babies.
- Levels of consumption of (1) milk and other dairy products (including cows', goats', and sheep's milk and home-made cheeses); (2) meat (including organ meat and meat jerky)

from small, medium, and large animals; (3) vegetables; (4) grains; and (5) wild fruits and berries.

- Sources of water for drinking and cooking.
- Hours per day spent outdoors in the summer.
- Type of building materials for the home.

The focus group moderator offered detailed probes in the form of open-ended questions related to each subject area. Then the moderator asked participants to estimate frequency and amounts of the foods consumed at different ages (1–4 y, 5–10 y, 11–15 y, and 16+ y). One study team member recorded answers from participants into each cell on the wall chart. Because participants in the first focus groups did not look at the charts at the appropriate times, the moderator began pointing to the food column at the beginning of each new set of questions, and the note-takers documented answers on spreadsheets or in written notes but not on the wall chart itself.

To the extent possible, answers were sought from each participant for every question. Because focus groups were limited to 2 h, there were occasions where some information was not collected. As a result, priority was given in the following order: milks and other dairy, sources of water, the most commonly consumed meats in that group, time spent outdoors, and building materials of homes.

Participants who preferred not to join a focus group or who found the timing or location of the focus group inconvenient were offered the option of participating in the study by completing an individual interview, typically conducted in the senior center or another convenient location. The type of information that was solicited in individual interviews focused on the family of the participant as well as community-level information. To the extent possible, an interviewer and a note-taker were present, but often the interviewer also had to take notes. As with the focus groups, the interviewer asked about the participant's diet, lifestyle, and home in the 1940s and 1950s and in 1945, if appropriate. The interviewer asked about the participant's recollection of the Trinity nuclear test, activities for summer celebrations and feasts, animals, and home gardens. In addition to the questions asked of focus groups, the interviewer also asked about community characteristics in the 1940s and 1950s, such as the percentage of homes that used water from each type of source, how milk was stored, sources of foods, and degree of access to grocery stores, markets, or trading posts. Quantified estimates of intakes and other relevant information from these individual interviews were merged with the corresponding focus group's data for a given community. Much of the information from the participant provided context for the differences in current lifestyle compared with that of the time period of interest as well as being useful for coding or interpreting the focus group data.

Study personnel offered all participants transportation to the meeting location from their homes in addition to

providing refreshments. Participants received \$50.00 to compensate for their time based on the recommendations of social science researchers who had extensive experience conducting community-based participatory research with Native American, Hispanic/Latino, and other communities in New Mexico. The senior centers received compensation for their collaboration and for providing space for the focus groups and interviews.

### Data analysis

We classified the geographic regions in which respondents had lived in the 1940s and 1950s as mostly plains, desert, or mountains; northern, central, or southern regions; and whether rural or urban. The urban centers were small cities that drew from populations living within the community or from the neighboring land.

Data were coded based on the wall charts or spreadsheets completed during the focus groups or based on the text from the note-takers. Spreadsheets were developed for each of the exposure topics by two coders. When both coders had been present at a focus group as note-takers, they each developed spreadsheets, which were then compared and harmonized based on audio recordings and recollections of those present at the focus group. When only one or neither of the coders had been present, they would read notes and listen to audio tapes or the audio from the Livescribe ballpoint smartpen, develop the spreadsheets, and later together decide the best code for each participant's answer if there were discrepancies in the coding. In addition, to confirm or clarify some issues, the coders consulted with the focus group moderator and team members who were present to obtain the best information for coding the data. Similar procedures were used to code the individual interviews by two team members, and any disparities were reconciled.

Table 1 presents the six datasets that were created by merging similar data according to ethnicity, ecozone, and rural/urban status. Almost all of the regions had information gathered from two focus groups and two individual interviews. Based on discussions with academic consultants in New Mexico, the small African American population was

presumed to have similar intakes and exposures to the Hispanic populations by ecoregion.

## RESULTS

Between July and October 2017, we conducted 13 focus groups—eight with Hispanic and White participants and five with Native American participants. Focus group size ranged from 4 to 12, with a mean of 6 individuals per group. We also completed 11 individual interviews in various communities, mostly at the same location as the focus groups and conducted concurrently. Earlier focus groups provided a greater cultural and linguistic narrative context that informed subsequent focus groups and interviews.

Some senior centers did not respond to requests to participate in the study, even after multiple visits by local collaborators and NCI team members. Two other senior centers scheduled focus groups, but either no participants arrived or potential participants had decided against the focus group. At one center, a few of those who decided not to participate in a focus group did agree to an individual interview.

Both the focus groups and individual interviews began with a food card sorting activity. Each participant was given a set of 10 cards with text and pictures of broad food groups on each card. The participants used the cards to indicate which foods were the most and least frequently consumed in their household and if a given food was not consumed at all. After the card-sorting activity, the moderator continued the focus group and went through each food category on the wall charts by age group starting with the youngest, and each participant provided their estimates of frequency and serving size. The large wall charts had grids of age groups on the rows and pictures of the food type in the columns (e.g., color pictures of pigs, cows, vegetables, legumes, and fruits). The wall charts did work well with setting the stage. The moderator would often walk toward the charts and point to each food group and asked about amounts of food consumed by age. Participants used their individual serving-size booklets so that they could see examples of varied serving sizes. Plates, bowls, and glasses were passed around between participants so that they could touch and

**Table 1.** Datasets applied to population strata for dose reconstruction as derived from merging focus groups and individual interviews.

Dataset	Region	Ethnicity <sup>a</sup>	Number of participants from focus groups and interviews
A	Rural/Plains	Hispanic	16
B	Rural Mountains or Plains/Mountains	Hispanic & White	16
C	Urban Mountains or Plains/Mountains	Hispanic & White	23
D	Rural/Plains	White	12
	Urban/Plains	Hispanic & White	
E	Mountains & Plains/Mountains	Native American	7
F	Plains	Native American	12

<sup>a</sup>African Americans were assumed to have similar habits to the Hispanics in each region.

feel each item and continue to become familiar with serving sizes on actual serving dishes. After the first focus groups, answers from respondents were documented by entering the data into spreadsheets or through long hand notes and not entered onto the wall charts. The variety of answers suggested that participants were fairly independent in their assessments. To ensure the focus groups were balanced, the moderator made sure to avoid having one person influence or dominate the responses provided by the rest of the group. This ensured that each participant gave independent intake responses.

Estimated mean intakes and standard deviations for the groups are presented in Table 2. The dosimetrists were provided with these data as well as the minimum and maximum for each age group cell. The lowest intakes of cows' milk were in the urban (small city) mountain communities in Dataset C and in the mountains/plains communities of Dataset E. The communities with the highest consumption amounts (Datasets A and D) were largely rural and with many ranching families that owned milking cows or received milk from neighbors. Intakes of milk from other animals were low for all respondents, although a few with lactose intolerance reported consuming goats' milk. Lactose intolerance rates ranged from 7% to 24% among Hispanic

and White communities and from 33% to 71% in Native American communities. Cheese consumption was very low, although participants did report the homemade soft cheese that would be consumed on special occasions. Some participants reported buying hard cheeses from a store and information about this source of cheese was not used in the dose estimations (i.e., coded as zero). Wild greens were consumed during the day outdoors and were difficult to quantify, but wild or garden greens collected for a meal were reported as quantity of cooked greens consumed per age category. Many respondents reported gardens with a variety of vegetables, including squash, carrots, turnips, corn, green beans, peas, potatoes, and legumes. It was not possible to obtain information on all these items, but it appeared that they were consumed in small amounts and that many represented a minor pathway of exposure. Based on information obtained in focus groups, it was estimated that these vegetables were consumed at about 20% the rates observed for leafy greens. Wild berries, plums and other fruit were consumed during the day while outdoors, and participants estimated consumption quantities for each type of fruit. Respondents often mentioned having very limited economic resources. They explained how they grew their own food and had simple diets of beans (legumes), corn, and homemade

**Table 2.** Mean (standard deviation) consumption data in mL d<sup>-1</sup> or g d<sup>-1</sup> by age group.

Foodstuff	Age, y	Consumption rate (mL d <sup>-1</sup> or g d <sup>-1</sup> )					
		A	B	C	D	E	F
Cows' milk	1-4	273 (98)	246 (154)	117 (75)	538 (257)	118	276 (225)
	5-10	617 (175)	471 (300)	172 (179)	531 (319)	237	395 (252)
	11-15	695 (264)	533 (386)	191 (201)	993 (418)	0	629 (373)
	16+	592 (424)	182 (256)	182 (256)	615 (540)	0	392 (288)
Cows' cheese	1-4	37 (45)	37 (45) <sup>a</sup>	0	0	0	0
	5-10	49 (20)	49 (20) <sup>a</sup>	13 (2.4)	0	0	7 (16)
	11-15	50 (18)	50 (18) <sup>a</sup>	21 (7)	0	0	11 (22)
	16+	50 (18)	50 (18) <sup>a</sup>	15 (2)	0	0	12 (23)
Beef/large animals	1-4	40 (6)	18 (15)	38 (16)	42 (33)	1.2 (2)	3 (4)
	5-10	78 (17)	39 (27)	71 (72)	88 (41)	9 (13)	5 (9)
	11-15	206 (87)	54 (28)	99 (116)	204 (86)	12 (14)	11 (10)
	16+	77 (93)	56 (32)	107 (125)	198 (64)	15 (17)	9 (16)
Mutton/pork (small animals for Data Set F)	1-4	4 (6)	0	8 (6)	22 (61)	0	11 (8)
	5-10	5 (6)	0	13 (10)	43 (74)	0	14 (10)
Leafy vegetables	11-15	8 (9)	53 (71)	16 (9)	109 (230)	0	26 (21)
	16+	8 (9)	53 (71)	8 (6)	200 (210)	0	23 (19)
	1-4	52 (35)	11 (21)	77 (67)	31 (21)	45 (64)	39 (52)
	5-10	122 (104)	23 (42)	220 (120)	90 (0)	71 (51)	88 (67)
Fruit and berries	11-15	217 (174)	45 (42)	251 (121)	103 (81)	122 (57)	170 (104)
	16+	263 (210)	143 (38)	290 (110)	165 (68)	193 (62)	279 (188)
	1-4	28 (20)	0	547 (410)	28 (20) <sup>a</sup>	5 (5)	109 (87)
	5-10	44 (47)	0	722 (344)	44 (47) <sup>a</sup>	9 (9)	173 (184)
11-15	76 (77)	0	1034 (446)	76 (77) <sup>a</sup>	14 (11)	218 (165)	
	16+	41 (36)	0	773 (337)	41 (36) <sup>a</sup>	20 (17)	284 (238)

<sup>a</sup>Data imputed from similar group (dataset A).

flour and corn tortillas. Most of New Mexico is at high altitude, and the population experiences seasonal differences in food intake. A seasonal subsistence and barter-based diet was common.

Breastfeeding was very common in all communities, with rates of 100% in most communities and of 82% in only one community. Although many men had difficulty reporting on the typical duration of breastfeeding in their communities, most participants reported that breastfeeding lasted at least 12 mo and often up to 24 mo (Table 3). Respondents also reported that lactating mothers did not eat special diets, and babies were introduced to cows' milk only after lactation ended.

As Table 4 shows, most community members lived in adobe homes during the study period, although one Native American community in a mountains/plains region built their homes with wood (Dataset E). In the preliminary investigation, pica emerged as a possible exposure route for participants in adobe homes. In response to this possibility, we asked questions about primary exposure to the external surfaces of homes (licking the outer walls of their adobe houses after a fresh external mud plater application). Intake of adobe surface was determined to be minimal.

Respondents were asked about the amount of time spent outdoors during the summer when they had no school. Most individuals reported being outside from sunrise to sunset in summer, except for some young children and girls, who were busy with indoor activities or chores. Respondents from three communities reported that able children and adults would sometimes sleep on the roof of their home at night because the air was cooler than inside. This was then specifically queried in subsequent focus groups but was not a common habit in other areas.

The large majority of communities reported having well water for drinking and cooking, and many wells were covered and had windmills. Buckets of water were brought into the home and covered until the water was used. Animals owned by the families would drink fresh water from the *acequias* (open water ditches or canals). One Native American community used water piped in from springs to parts of the village, and families would bring buckets of this water home for drinking and cooking. Almost no communities reported collecting rain water for cooking and drinking,

**Table 3.** Breastfeeding duration by data set.

Data set	Mean number of months (standard deviation)
A (Rural Plains)	10.5 (4.5)
B (Rural Mountains)	16 (4.4)
C (Urban Mountains)	13.9 (5.2)
D (Rural & Urban Plains)	13.9 (5.5)
E (Mountains and Plains)	12
F (Plains)	21 (5.6)

**Table 4.** Percentage of participants reporting types of housing materials.

Data set	Construction material of participant homes (%)		
	Adobe	Wood	Other
A (Rural Plains)	78	11	11
B (Rural Mountains)	91	9	—
C (Urban Mountains)	73	27	—
D (Rural & Urban Plains)	50	17	33
E (Mountains & Plains)	—	100	—
F (Plains)	100	—	—

although they did use rain water for bathing, watering the garden, and washing clothes. The moderator deliberately probed multiple times about the collection and use of rainwater to ensure there was no misunderstanding and to obtain specific information about this potential source of contamination.

Often, the focus groups began with discussions of contrasts between current daily life and daily life during the study period. The foods were largely from a local source, and some foods were no longer available. Many groups discussed the fact that resources were scarcer during the study period than they are now, how they managed with limited resources, and that nothing was wasted. Participants reported that each family member ate all the food provided on the plate, unlike their current grandchildren who have many food options and often do not finish all the food on their plates. All family members helped with needed family activities, such as working in the fields, house chores, and taking caring of siblings.

One of the hallmarks of an effective focus group is creating open communication that is free of judgement and feels like a conversation instead of answering a series of questions. By comparison, an unsuccessful focus group is one in which there is no open communication environment that allows participants to share and contribute to discussions. The success of the focus groups and individual interviews were demonstrated by the level of detail participants provided about life in New Mexico when they were growing up and their willingness to answer questions. For instance, participants were able to recall the locations and types of wild spinach and fruits they picked and ate during the summer months. They described the location of the wells in their community and even the name of the family that lived next to the well. Among participants that drank cow's milk, they shared whether the milk came from a local dairy or a cow that lived in their community. Participants that drank milk from a goat shared which members of their family were not able to digest cow's milk. The variety of reported intakes from participants across food types further demonstrates that all participants were able to provide individual responses. At the end of each focus group, participants shared how much they enjoyed talking about what life was like when they were growing up. Data from all focus groups and individual interviews were used.

Data from appropriate earlier studies were used to derive uncertainty factors for use with the dose estimations to characterize what we believe to be the credible range of mean values of consumption rates and lifestyle factors. Although no previous studies that we relied upon for estimating uncertainty used focus groups or had such a long recall period, the mean differences and standard errors from studies with 10 or more years between recorded and recalled data were used to derive best estimates of the uncertainty factors (Friedenreich 1992). We applied smallest uncertainty factors to the data from the best focus groups, based on the moderator, nutritional expertise, and evaluation of spreadsheet data. Then more conservative uncertainty factors were derived for the focus groups that were deemed less reliable. Further discussion of the use of uncertainty factors in the dose estimation is provided in Simon et al. (2020).

## DISCUSSION

The data collection team's observations suggested that having open discussions about life during this period appeared to have aided recollection among all participants within each focus group. Engaging in collective discussions during the focus groups seemed instrumental in setting the stage and potentially improving recollections. Participants built on each other's memories, which allowed most participants to report on summer practices as well as details of how foods were prepared and consumed. The team's practice of translating all instruments, speaking in the preferred language (Spanish or English), or even simply asking the participants which language they preferred likely aided in their engagement in the activities. Other manners in which the team demonstrated respect for the participants' culture included opening with a blessing, sharing a meal, and use of time-period-appropriate dishes, clay bowls, and cooking pots. Collecting consistent answers across similar but separate focus groups suggested some indirect validity and should improve the estimation of dose, also confirming that the attention to culture was effective in all groups who engaged in this research.

Review of previous studies on recall of the past diet, particularly distant past, revealed several consistent conclusions (Willett 2013; Friedenreich 1992), although no studies were reviewed that had a 70-y time-lapse. More reliable recall was observed for studies that used interviews rather than self-administered questionnaires and that recall is most reliable for foods eaten rarely or with a high stability over time. Although advancing age may be associated with decreased ability to recall past dietary intakes, long-term memory often remains intact despite loss of short-term memory in older adults (Krall et al. 1988). Recollections may be improved by asking about specific foods rather than grouping food items together, asking about individualized portion size is superior to

asking about frequency of a standard portion, and using detailed methods for estimating portion size increases correlations between original and recalled diets. These results suggest methods used in the focus groups are consistent with suggested practices for obtaining information on past diets. In addition, having had very limited variety in diets in the time period of interest may have helped with the recollection for the items being queried.

The specific amounts of foods that participants reported were representative of the typical diet for children of specific ages and ethnicities with which they were familiar. We based our methodology on previous research in which we compared self-report against focus group data in a similarly exposed sample. In 1998, in an epidemiological study of individuals exposed to radiation from nuclear testing during their childhood and adolescence in Kazakhstan between 1949 and 1962, the NCI, the Semipalatinsk State Medical Academy, and the Kazakh Research Institute for Radiation Medicine and Ecology similarly collected food and behavior information using a basic questionnaire. In that study, the outcome of interest was the effect of radiation exposure on the development of thyroid nodules. In 2007, the NCI conducted focus groups with older adults in Kazakhstan to obtain detailed information on milk consumption and other exposures of interest in 1949 and early 1950s (Schwerin et al. 2010). In that study, the response data from the focus groups improved the analyses of the thyroid radiation dose estimates for participants from the previous epidemiological study compared to the self-reports on the basic questionnaire (Drozdovitch et al. 2011). Based on lessons learned in that study, we used similar strategies and methods in the Trinity study.

Previous research indicates that the card sorting method used in this study could facilitate memory recall among senior citizens (Craik et al. 1990). In our study, participants would often talk out loud to themselves as they sorted their individual set of cards and comment on the types of foods. For example, participants quickly identified which foods they did not eat and took more time to sort through the foods that they consumed more often. Performing the card sorting before engaging in the focus group discussion appeared to help orient the participants to the time period of interest and perhaps reduce the influence that may have resulted from fellow participants. As a result, implementing the card-sorting approach afforded a reliable way for participants to remember which foods they ate most often and focus on the time period of interest.

Providing participants with serving bowls, plates, cups, and utensils from the 1940s and 1950s offered a tactile way to remember the foods they ate at the time. As participants engaged in the discussion, they often held a bowl or plate and compared it with the types of plates their families had used. Many participants reported having used the same styles

as those on the focus group table or in the pictures on the wall. Furthermore, participants reported on community celebrations, which were highlights of the summer and featured unique foods (e.g., meat from cow or pig) that were shared and involved preparation, planning, and collection of resources. The fact that focus group participants were able to recollect summer activities and lifestyle differences helps provide confidence in the many estimates, particularly for time spent outdoors for each age group.

### Validations, limitations, and uncertainty

Given that the year of exposure (1945) is more than seven decades in the past, there are clearly limitations of our data collection, issues of data validation, and uncertainty that require discussion. One important point is to recognize that the data we collected are for a risk projection study rather than an individual dose assessment and, accordingly, are not intended to represent any identifiable individual but, rather, represent typical behaviors of the identified group. In some instances, certain types of information were found to be more difficult for participants to report on compared to other information. Hence, the reliability of reported values is not necessarily equal across all food types and lifestyle parameters. While it might be possible to argue against specific data that we report, the values we present can be attributed to the participants in our study and for that reason are believed to have a firm basis in genuineness. Moreover, because questions in the focus groups and interviews were phrased to elicit responses about families and general community members, the responses obtained are expected to have a degree of representativeness of the communities at large.

We had originally planned to compare the collected data to appropriate national survey data as a means of validation, but we found no comparable data from such surveys conducted during the time period of interest (Tippett et al. 1999). Specifically, there was no survey on diet that isolated the state of New Mexico during our study period, although the 1955 survey data (USDA 1957) included 11 diverse western states that spanned from the south to the north of the country. There are household-level dietary data collected in a nonrepresentative nationwide study of homemakers in 1942 (USDA 1944), which queried about quantities of listed foods used by the household the previous week. This “7-day food list” method was used in a nationally representative survey in 1955 (USDA 1957). Based on the average of data from the 1942 and 1955 surveys, household milk consumption averaged 456 mL d<sup>-1</sup> for urban, 452 mL d<sup>-1</sup> for rural non-farm, and 870 mL d<sup>-1</sup> for rural farm communities. These data are consistent with our findings of higher intakes in the rural farm communities. However, we could not use the 1942 and 1955 survey data to derive measures of validity for our data because our findings differed greatly by age

group, we did not measure household consumption, and none of the surveys conducted during our study period collected information from the unique ethnic and racial groups populating New Mexico or similar surrounding states at the time.

Although the main purpose of the initial literature review was in preparation for data collection, it later indirectly validated data collected in our pilot testing, focus groups, and interviews. For example, water sources, types of feasts and celebrations, and types of foods consumed during the summer in our study were similar to those found in the literature review and in pilot testing. Moreover, similarities were found in the responses both in the one-on-one interviews and the focus groups. The same types of foods were consumed among similar ethnic groups across the state of New Mexico. Picking a flowering wild plant commonly called “cota” or *thelesperma filifolium* and using it to make tea was a common practice among all Native Americans. Whites consumed more milk in comparison with Native Americans and Hispanics. Collected exposure data were recalled with various degrees of difficulty. There is uncertainty of the reported milk consumption rates, though the consistency within and across focus groups from the same region supports validity. Some groups had high intakes because of the availability of milking cows, and low intakes were related to the reverse. The reporting on lactose intolerance seems quite reliable because participants knew exactly who in the family could or could not have consumed fresh milk. Therefore, these prevalence estimates can be used with confidence. Intakes of meats were low in most cases and clearly reported, so these estimates should have good reliability as well. Intakes of leafy green vegetables were recollected well, but the participants had more difficulty quantifying fruit intakes. Many participants had little difficulty reporting the prevalence and duration of breastfeeding in their families, although others could not provide any information on this topic. Almost all participants easily reported on the sources of water their families used, building materials of their houses, and time spent outdoors in summer. These data are presumed to have been reported with the greatest accuracy of any of the questions, suggesting that they can be used for the dose reconstruction with high level of confidence. As discussed earlier, uncertainty factors were derived for each of the data sets depending on the subjective assessment of reliability by the moderators and previous studies in the literature.

### CONCLUSION

The methods and logistics applied as described appeared to have worked well in that they resulted in clear engagement of the participants and ultimately in delivering data useful for the dose estimations. Effective methods used by the study

included enlisting the help of Senior Centers and interested Native American tribes, screening participants, involving local consultants, and the approaches used in the focus groups. The props and pictures were of interest to the participants and helped with orienting them to the distant past as evidenced by their comments. The audio recordings and independent coding of the data helped ensure reliable estimates based on the information provided by participants. Much of the data collected from the individual interviews were similar to those collected from the focus groups, and this overlap adds confidence in the reliability of the data, particularly at the community level. Although some focus groups were more reliable than others, grouping the data by ethnicity and ecoregion helped provide more stable estimates of the exposure-related variables, and the standard deviations provided information on the variability in the answers. Finally, similarities in answers within region across focus groups and individual interviews was useful and improved our confidence in the estimates. The data collected and presented here are further summarized in the context of development of exposure models (Bouville et al. 2020) and are subsequently used to derive estimates of radiation doses across the state (Simon et al. 2020). The collected data are of the best quality possible given the long passage of time and sparse published information on diet and lifestyle in New Mexico in the mid-1940s.

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