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Principal Investigator: Foster, RoseMarie Perez

Organization: University of Colorado, Boulder – Natural Hazards Center

Title: Long-term Psychosocial and Health Behavior Outcomes of Perceived Radiation Risk and Physical Radiation Exposure Risk to Caesium-137, in the Ukrainian Chornobyl Disaster Population: Major Findings to Date Based on a Preliminary Analysis

Submitted by: Foster, RoseMarie Perez, PI

ABSTRACT

The current report describes a preliminary analysis (n=281) of a random population sampling of Ukrainian residents living in the Kiev and Zhytomir oblasts (states) of Ukraine, who were exposed to the Chornobyl Nuclear Station accident in 1986. The total sampling of n=700 and final analysis is projected for 09/2012. Conducted with support from the U.S. National Science Foundation's section on Decision, Risk and Uncertainty, and with collaboration of the Ministry of Health of the Government of Ukraine, the study aims to describe the complex bio-psycho-social pathways that contribute to long-term outcomes in the affected population. Predictive models of radiological disaster risk are sought to understand psycho-social, health behavior, cognitive and mental health factors in the exposed population. The perception of radiation health risk from the Chornobyl accident is considered against a reconstruction of study respondents' estimated cumulative exposure to the source term, Caesium-137 (Cs-137), since the time of the Chornobyl accident. The main findings of the current analysis are: 1) Actual physical risk from estimated cumulative radiation exposure to Cs-137 from the Chornobyl accident is low, and below levels of significant biomedical clinical jeopardy. 2) Cognitive perception of radiation health risk from the Chornobyl accident is high, and has continued to increase over time. This long-term perception of health jeopardy may be unique to radiation and other toxic disasters

3) Perception of radiation health risk at over twenty years post-disaster, is not statistically related to overall mental health distress, or compromises in paid employment or familial role functioning. There is evidence of a relationship between perception of Chornobyl health risk and self-reported sub-clinical symptoms of depression and health-related social inhibition. It is unclear, however, at this point in the analysis whether the latter are pre-disposing substrates for disaster-related reactivity, or radiation disaster sequela per se. 4. Proactive maintenance of home care cleanliness as directed by public messaging in the initial post-Chornobyl period, has significantly mitigated health anxiety associated with radiation exposure across the 25 year post-disaster period.

The long term outcomes of large-scale nuclear industrial accidents are of key importance as countries move towards alternative nuclear energy sources, and engender the risks of large-scale spillage, as evidenced by both the Chornobyl (Ukraine, 1986) and Fukushima Daiichi (Japan, 2011) plant disasters.

1. INTRODUCTION

The cognitive perception of risk by communities exposed to radiologic and other toxic disasters (i.e. chemical, biological), emerges as a significant predictor of long-term health and psycho-social behavior sequelae in exposed communities. [(1).] However the multi-determined dynamics of these risk perceptions are only moderately understood, particularly in their critical relationship to empirically quantified levels of physical exposure to the source toxin, or “actual risk”. For human groups, the concept of nuclear energy, for example, and its containment, is underscored by powerful negative symbolism and a social amplification of its risks. Common public perceptions articulate a unique dread of radiation as a mysterious entity that is capable of perpetrating illness, transgenerational birth anomalies, large numbers of human fatalities, and potential world-destruction. [(2,3,4)]

The last decades have witnessed several highly publicized technological malfunctions at nuclear power plant stations and storage facilities. Whether incidents consist of low-level or possible radiation leakage into surrounding areas such as Windscale in England (1957), Lubmin in East Germany (1976), and Three

Mile Island (TMI) in US (1979); or full nuclear reactor meltdown in Chornobyl , Ukraine (1986), the pervasive response of local residents and the general public has consisted of dread reactions to an uncontrollable threat.[1,5] Lay people show higher perceptions of health risk due to radiation, than experts or scientifically informed professionals.[6,7] Prior to TMI, nuclear plant accidents were viewed in the US as leading to scenarios of nuclear war proportion destruction. After the TMI event these images were even more severe.[8]

In Europe, The Chornobyl nuclear reactor malfunction released the largest amounts of radionuclides ever produced by an industrial accident. This event became a cascading disaster of 100,000 relocated residents, pollution of air, food, and water supplies in Ukraine and other FSU and European regions, and a complex host of medical and psychosocial sequelae in the affected population, that still command ongoing assessment and post-disaster intervention.[9,10,11]

For the Ukrainian population, the accident deeply compromised a broad spectrum of bio-psycho-social factors. These outcomes have been abundantly described in the academic literature: The attendant increases in thyroid carcinoma for exposed individuals,[12,13] high medical services utilization,[1] shifts in agricultural economies and employment,[13,14] and human behavioral changes generated in response to living in an irradiated environment, [15], have left indelible long-term markers on a country exposed to the largest industrial radiation accident in history. Now at 25 years post disaster, new investigative strategies allow us to explore complex interactions between human populations and environment over time, and the factors that have continued to impact on the psychosocial and health-related functioning of the exposed Ukrainian population.

2. CURRENT STUDY AND RESEARCH QUESTIONS

The current study was initiated in the Ukrainian oblasts of Kiev and Zhytomir in 2008. Data collection is still underway. This is the first report of the Ukrainian sampling, providing a preliminary analysis of 281 respondents. Investigators offer interim descriptions of how the 1986 radiation accident impacted on long-term perceptions of health risk to self and family, perceptions of localized pollutants, health-related impacts on social, familial, employment, household and leisure functions, and a broad spectrum of mental health symptomatology. These factors are considered against the quantitative reconstruction of estimated cumulative radiation exposure levels to the radiation source term: Caesium-137 (Cs-137), since the time of the 1986 nuclear plant accident. Cs-137 has a half-life of approximately 30 years, for which reason this isotope would be a source of radiation concern for Ukranians living near Chornobyl. Data were acquired for 3 time periods: wave1- from date of accident, April 26, 1986 to December 31, 1986j; wave 2-January 1, 1987 through December 31, 1996; and wave 3-January 1, 1997 through December 31, 2010.

In the analysis reported herein, particular focus was placed on the construction of interim models that would explain the sample's perceived health risk from exposure to Chornobyl radiation, and actual biomedical risk estimated from their cumulative external dose exposure to Cs-137. The primary research questions at this time were: Is there a relationship between exposed respondents' perception of radiation health risk and individually reconstructed cumulative radiation Cs-137 dose from Chornobyl radiation? How do reconstructed levels of cumulative radiation dose relate to a broad range of health-related functional behaviors? Is there a relationship between the perception of risk and compromises in mental health? Finally, is there a relationship between geographical proximity to the Chornobyl nuclear station and the perception of radiation health risk among the general population?

The final analysis upon completion of data collection at n=700 will permit application of Bayesian strategies for respective spatio-temporal mappings and statistical comparisons of: radiation dosimetry distribution of Cs-137 in Ukraine; perception of radiation health risk; and distributions of health-related behaviors, psycho-social functioning, and disease prevalence. The concept of risk perception mapping for technological risk has been previously been described by Hung and Wang(16) and Stoffle et al(17).

The current project's design emerges from an integration of social behavioral science and the physical sciences of radiation dosimetry and medicine. The investigator team spans the disciplines of radiation physics, risk analysis, medical and psychiatric epidemiology, and disaster sociology and psychology. The cooperating institutions in the study are: the National Science Foundation, division of Decision, Risk and Uncertainty; University of Colorado at Boulder, Institute of Behavioral Science, Natural Hazards Center; Colorado State University, Institute of Radiation and Health Physics; Ministry of Health of the Government of Ukraine; Ministry of Communication of the Government of Ukraine; Kiev Union of Young Psychiatrists; and the Academy of Labour and Social Relations of the Trade Unions of Ukraine.

3. METHODOLOGY

3.1 *Basic Procedure:*

The study conducts a random sample of residents in the Kiev and Zhytomir oblasts (states) of Ukraine. These oblasts include urban, township and rural/agricultural residential areas. Nine trained native interviewers (3 PhD, 3 MD, 3 MA) administer a 1 ½ hr. survey questionnaire to consenting participants in their homes upon signature of informed consent. Participants are compensated the equivalent of $20 USD. The survey questionnaire is constructed in an electronic format mounted on interviewer hand-held computers. Upon questioning, respondents' data are automatically entered, uploaded and maintained on a secured designated website that is managed by Vovici Corporation, USA and the University of Colorado at Boulder, Institute of Behavioral Science.

A pilot study was initiated in winter 2008 on 100 respondents. Within this time the electronic survey instrument was tested; the sampling frame was constructed; the statistical viability of instruments and procedures were tested; dosimetric map data were acquired for Cs-137 deposition in Ukraine from the International Association of Atomic Energy (IAEA), and methodology was designed for radiation dose reconstruction. Formal data collection was initiated in October 2009, and the survey questionnaire responses of the first 281 interviews were analyzed with basic statistical procedures. The current paper reports on a sample description of these 281 respondents, radiation dose reconstruction procedures, data trends, preliminary model construction, and proposed statistical strategies that will be implemented upon completion of sampling at n=700.

3.2 *Participants/Sampling Procedure:*

Study participants in this sample segment are 28-84 years of age. The random sampling of Kiev and Zhitomyr Oblast residents began in 2009 and is still under way. Telephone numbers were randomly generated by computer for the area codes in each oblast. These codes were provided by the Ukraine Ministry of

Communication. The phone numbers were called with a maximum of four callbacks to obtain consent on the part of respondents to participate in the survey. The total number of home telephones in the Kiev and Zhiyomir oblasts at the beginning of our sampling period was tallied by the Ministry to be 1,637,389. This total was subdivided according to area code. At the time of total data collection this information will allow us to construct sampling weights by inversion of the probability of selection for each respondent. However for this preliminary analysis of 281 respondents, we are not using sampling weights, but relying on model-based inferences for the time being until all data collection is completed. We understand that although the large portion of the population has a home telephone, not everyone does. Some sampling bias can derive from poor, transient, and or homeless people not likely to have a home phone.

3.3 Study Instruments:

The survey questionnaire (SQ) is comprised of several sections formulated in both Russian and English languages. Russian instead of Ukrainian language was chosen given that sampling cohort (ages 28-84) was educated during the period of Russian language dominance when Ukraine was a part of the former Soviet Union. The SQ is an interactive electronic instrument that is accessed by interviewers in the field from hand-held computers. The SQ sections include a radiation exposure profile, a perception of risk profile, four standardized mental health and health behavior scales [Nottingham Health Profile , Brief Symptom Inventory-BSI , Mississippi Civilian PTSD Scale], medical ICD 9 (International Classification of Diseases) diagnoses collected from the national Ukraine Health Registry, a perception of general and radiation risk profile, life buffers, life stressors, major disruptive life experiences, economic and employment status and functioning, self-reported illnesses, multi-domain health behaviors, knowledge and sources of Chornobyl accident information, scientific knowledge about the dynamic spatial and temporal impact of radiation on health and environment, and demographic information. These queries are posed across time frames since the radiation disaster, with the goal of conducting both longitudinal panel assessments and survival analyses at the completion of data collection.

a. **Radiation Exposure Profile:** Following established international protocols in radiation health physics and Chornobyl studies in particular[18, 12], the SQ queries factors that will render individual respondent reconstructions of cumulative external exposures to the specific radioactive source term: Cs-137. These include the following data for formulaic dose reconstruction: all residential locations and lengths of stay since 1986, their geographical coordinates, residential dwelling construction features, dietary habits, food purchasing locations, and outdoor exposure by occupation.
b. **Perception of Risk Profile:** This domain of questioning was informed by theoretical paradigms and research findings that currently form the knowledge base on human perception of health and toxic environmental threat . Queries will thus render information on general health risk attitudes, radiation health risk perceptions, toxic environmental risk perceptions, social amplification of risk, academic/scientific knowledge of radiation dynamics, knowledge of the Chornobyl disaster event, information sources for the event, and degree of trust in sources.

   Nottingham Health Profile This is a standardized mental health instrument used for assessment of perceived health problems. It has been extensively tested among divergent community groups in both research outcome and clinical contexts. The profile is designed to determine and quantify the severity of health symptoms (part 1) and health impact on multiple domains of functional behavior. (Part 2). Face, content and criterion validity have been tested in various European studies, showing the profile to be a reliable indicator of subjective health impact on physical, social and emotional domains of functioning. [19] Reliability tests conducted by the current study demonstrated adequate Cronbach's alpha for this interim analysis.
c. **Basic Symptom Inventory (BSI)** This is a standardized tool for identifying self-reported clinically relevant psychological symptoms in adults. The BSI consists of 53 items that cover 9 symptom dimensions: somatization, obsession-compulsion, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation and psychoticism, as well as 3 global indices of mental health distress. Good internal consistency reliability for the 9 dimensions is reported by several studies.[20,3] The Inventory has also been

successfully correlated with both the MMPI and the SCL-R-90.[20,21] Translated and revalidated by primary investigator on Russian-speaking sample, showing healthy internal consistency (alpha=.86). Reliability testing for the global indices used in the current study showed high internal consistencies, with Cronbach's alphas ranging from .85-.97.

d. **Coping Strategy Indicator (CSI)** The CSI has been broadly tested in community samples yielding robust reliability and validity scores.[2,23] The CSI consists of 33 items that test for 3 major strategies that characterize coping behavior: Problem Solving, Seeking Social Support, and Avoidance. While adequate internal consistency emerged in the pilot study for the current investigation, reliability testing conducted for the current analysis of n=281 yielded questionable adequacy (Cronbach's alpha = .60). The questionable appropriateness of this scale for use with the current cultural population may be further borne out in the fact that no outcomes for this measure were found to be statistically significant in the current study. The final analysis should yield further information.

e. **Civilian Mississippi PTSD Scale** A 30 item scale combining measurements of general distress and test items "anchored" to a specific traumatogenic event.[24] Demonstrates good internal consistency (alpha=.86) and adequate criterion validity when correlated with other measures. Translated and revalidated on a Russian-speaking sample showing good internal consistency (alpha=.88).[25,26]

f. **The *International Statistical Classification of Diseases, 9th Revision* (ICD-9)** was used to designate respondents' medical illnesses from year 1980, as recorded in their medical charting records provided by the Ukraine Ministry of Health. The ICD-9 is a coding system of diseases, symptoms, abnormal medical symptoms and external causes of injury and disease developed and maintained by the World Health Organization. The current study uses the ICD-9 vs the most recent ICD-10 version, given the latter has not yet been incorporated into statistical software. The system is commonly used in international clinical and research contexts.

3.4 Quantitative/Statistical Procedures:

a. External Radiation Dose Reconstruction Procedure (Cs-137)

The European Commission and the IAEA published the *Comprehensive Atlas of Caesium Deposition on Europe after the Chernobyl Accident.* [27] The *Atlas* contains detailed projection maps of deposition contours that are color coded to represent Cs-137 concentrations. The maps were originally projected into an oblique azimuthal projection, but were converted into an equirectangular projection through a vector graphics package in order to facilitate data acquisition. A very small number of points outside the Ukraine were acquired manually instead of automatically. Cs-137 deposition for Asia was approximated using the deposition of easternmost Russia.

Grids of Latitude and Longitude were juxtaposed with the maps. Software was developed by current Investigators to recover the color Cs-137 concentration at a specified Latitude and Longitude for each residence specified by a subject obtained from the Survey.

The effective dose, E, from external radiation exposure from radioactivity deposited on the ground is modeled in the following way:

1) Determine the dose rate in air based on the Cs deposition at the location as a function of time
2) Application of an age-dependent factor that converts dose to air into effective whole body dose to the individual, $K_{a,i}$
3) Include modifying factors that include fraction of the time spent outdoors, $f_{a,o}$ and attenuation factors L_H associated with occupancy f_H in building and dwellings,

$$E = \sum_i \sum_R f_R \sum_o f_o \sum_H f_H \bullet L_H \bullet K_{a,i} \bullet \int D_{R,i}(t)$$

The results are presented as the estimated external cumulative reconstructed dose for Cs-137 as a function of time following the accident.

b. Statistical Procedures

The study is in its initial phases of data analysis, with complete data collection and final analysis projected for 2012. The current preliminary analysis of a sampling of 281 respondents includes the following statistical procedures:

- *Probability sampling of two Oblasts*
  Random digit dialing household telephone survey
- *Scale analysis*
  Reliability analysis
- *Graphical exploratory data analysis*
  Distributional analysis of endogenous variable
  Dimension reduction techniques where needed
  Identifying functional forms of relationships with endogenous variables (28)
  Linear transformations where appropriate
  Nonlinear model consideration (intrinsically nonlinear relationships)
  Regression splines + linear relationships(29)
- *Methodological tournament*
  Bivariate screening for variable selection
  Data mining with effective degrees of freedom
  General to specific modeling strategy (30)
- *Regression partition analysis*
- *Hierarchical logistic regressions: Wave 1, Wave 2, Wave 3*
  Bayesian protocol application for imputation of missing values (Little & Rubin, 1987)

4. PRELIMINARY FINDINGS and DISCUSSION

4.1 Pilot Study:

A random telephone pilot study of households was conducted in autumn and winter of 2008 and 2009. Phone numbers were randomly generated with Stata10 and 11 MP. After 100 respondents were collected, the pilot study was analyzed for basic information needed to plan the general survey. From the pilot study, we obtained a response rate based on the number of phone numbers generated to obtain the sample size needed. We determined the sample size needed by an a priori power and sample size analysis for each of the statistical techniques that we had proposed. We estimated that we would need 397 respondents to detect a small-to-medium regression model effect size R^2=0.055 using 21 explanatory variables with a power of 0.90 at a significance level of 0.05. Our objective is to obtain 700 respondents from the full survey, such that there will be sufficient power to perform gender-specific separate analyses.

The Survey Questionnaire (SQ) pilot findings formed the basis of population focus groups conducted for inquiry and review of findingys and cultural correctness of questions and interview protocol. The PI is also an experienced researcher with populations from the former Soviet Union. Russian language translation of 3 of the 4 standardized mental health/psychosocial scales was conducted with permission of original authors through the traditional translation/back translation technique. Reliabilities for all 4 scales were generated and found to be satisfactory for the current population of Russian-speaking respondents from Ukraine. From the pilot study, it was learned that exact dates should not be queried, but rather time ranges. We learned that recall was a problem when too much detail was asked regarding events that had occurred too long ago. Consequently, some questions were dropped and others refined. Pilot study findings were integrated into the final SQ, which was then translated into an electronic software application by Vovici Corporation in US. This application was made compatible for laptop computers that were programmed for interviewing in the Ukrainian field.

4.2 Sampling of 281 Cases:

Sample Description

Residential Geography: The 281 participants were recruited by means of a random selection of household telephones in each oblast, by means of the area codes within each respective oblast (elaborated above). Four respondents were deleted from analysis due to being only ones from an area code. 44% are from the Kiev oblast and 56% from Zhitomyr. The sample emerged from the cities or towns of: Kiev, Zhitomyr, Berdichev, Boyarka, Barishevka, Korotich and Visheve.

Gender: The sample for both oblasts at this point in time as it is being collected consists of 70.5% (198) women and 29.5% (83) men.
Age distribution: Respondents are 28 to 84 years old. The mean age is 52.7. The standard deviation is 13.3.
Education: This is a highly educated sample that is skewed towards technical and higher education, where well over 50% received education post high school. Approximately 39.5% received specialist or master's degrees; and 38.08% received technical degrees. Four reported doctoral level degrees.

Partnership/Family Status: When we examine the marital status of the sample, most (68.5%) are married. About 14.5% report being widowed. 7.44% say that they are single. There are only about 4.96% who say that they are divorced with only 1.7% admitting to cohabiting. 3.31% say that they are separated.

Family size: The majority of families in our sample at this time (52.07%) have 2 children. 25.6% of the families report having one child. About 13% have no children. Large families are less common. All those who report having children so far claim that they have no more than four children.

Employment Status: 53.72% of our sample reports having a full-time job; while only 2.48% maintain that they work part time. Almost a third of our sample (31.4%) indicates that they are retired. 11.57% say that they are unemployed.

Occupational Status: 12.4% of those in our sample report having a professional, executive, or managerial (administrative) position now. 7.44% maintain that they do technical, sales, or administrative support work. 3.31% report jobs in protective services or a service occupation. 14.05% are involved in homemaking or caregiving. Less than 2% admit to doing factory labor, machinist, transportation, or cleaning work. The same percent reports doing farming, fishing, forestry, trapping or logging. A large majority of females occupy the professional/executive positions as well as the homemaking kinds of work.

*Job Satisfaction: W*hen asked how happy in terms of percent they were with their job, we asked this question with respect to three waves: Wave 1: Apr. 26, 1986 – Dec. 31, 1986; Wave 2: 1987-1996; and Wave 3: 1997-Dec. 31, 2010. The respondents revealed that a plurality reports being very happy with their jobs at the present time (100%). In Wave 2 almost half of the sample (51%) reported being 100% happy with their jobs. However in Wave 1 around 1986: 65% reported being 100% happy with their job.

4.3 Dose Reconstruction for Cs-137

Cumulative reconstructions of external exposure to Cs-137 were performed for three "cumulative radiation time waves": Wave 1-April 26, 1986-Dec. 31, 1986; Wave 2-April 26, 1986-Dec. 31, 1996; Wave 3- April 26, 1986-Dec. 31, 2010. The parameters for these cumulative radiation periods were established by previous Chornobyl studies. The source of radiation responsible for external dose to study participants originates from radioactive fallout deposited on the ground following the Chornobyl accident. There were no personal dosimeters available for individuals and thus estimates of the accumulated dose are obtained from a retrospective dose reconstruction process conducted by the current Investigators. This cumulative dose is derived from locations of residency, dates at each location, time-dependent Cs-137 concentration in soil at each location, age-dependent dose factors, type of dwelling and occupation. The distribution of reconstructed dose for 281 persons, in units of μGy, is shown in Fig. 1 and summarized in Table 1.

Figure 1: Reconstructed cumulative dose for Cs-137 in study sample

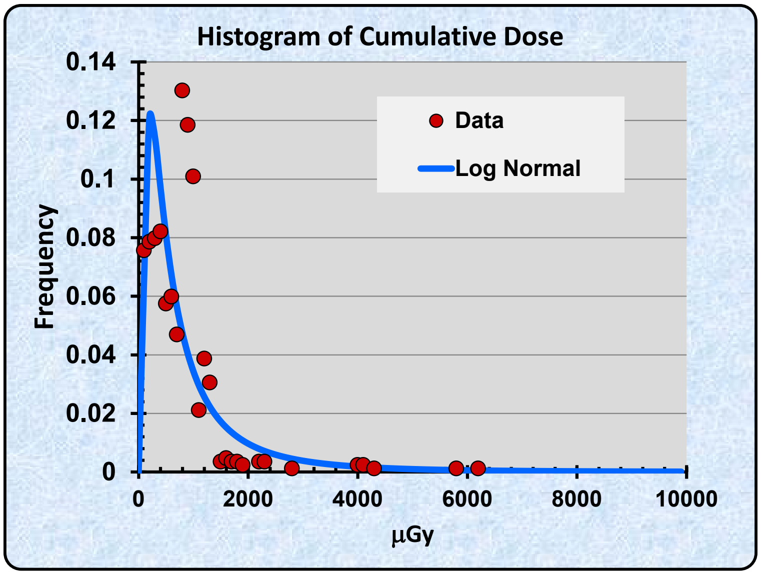


Table 1: Summary statistics for reconstructed cumulative dose for Cs-137

Table 1	
	µGy
Minimum	44
Maximum	26600
Mode	800
Median	715
Mean	838
Standard Deviation	1695
Geometric Mean	550
Geometric Standard Deviation	2.4

The graph and table show a very large range of accumulated doses that spans almost three orders of magnitude. The blue curve in Fig. 1 is a log normal distribution based on the geometric mean and standard deviation listed in Table 1. It should also be emphasized that all of the estimates of external dose for this sample of respondents are extremely small. It is impossible to identify any clinical or biophysical response of any kind for these doses. The level at which spontaneous human biological effects might be expected exceeds the magnitude of the estimated external dose reconstructed here. In addition, there are other sources of external radiation, unrelated to Chornobyl accident fallout, that are responsible for much larger doses. Some estimates of these doses as well at statutory limits are listed in Table 2.

Table 2: Statutory limits for other sources of external radiation:

Source	**Annual rate (μGy/y)**	**20 year Cumulative (μGy)**
Natural Radioactivity in soil	200	40,000
Cosmic Radiation	300	60,000
Regulatory limit for workers	20,000	400,000
Regulatory limit for general public	1000	20,000
Most probable value (mode) from dose reconstruction for first 281 respondents		800

4.4 Comparing Reconstructed Dose (Actual Risk) with Perception of Risk:

In order to explore the nature of the relationship between physical reconstructed dose (actual dose) and the public perception of radiation risk, we examined plots of bivariate relationships(31) We observed a nonlinear relationship between the respondent's self-reported health risk due to Chornobyl and Cs-137. To render this relationship more amenable to analysis by linear statistical methods, we apply the natural logarithm transformation to the cumulative external dose from radioactive fallout. See Figure 2 for increases in cumulative dose of Cs-137 by wave (these cumulative doses calculated to 2009). Even more disconcerting is the possibility for outliers to distort non-robust estimates of a mean by conventional statistical analysis. The lowess smoother gives more weight to observations closer to the point of estimation, so as to attenuate the influence of any outliers. After the natural log transformation, the lowess smoothers reveal the gradual increase over time.

Figure 2: Cumulative reconstructed dose for Cs-137 by wave:

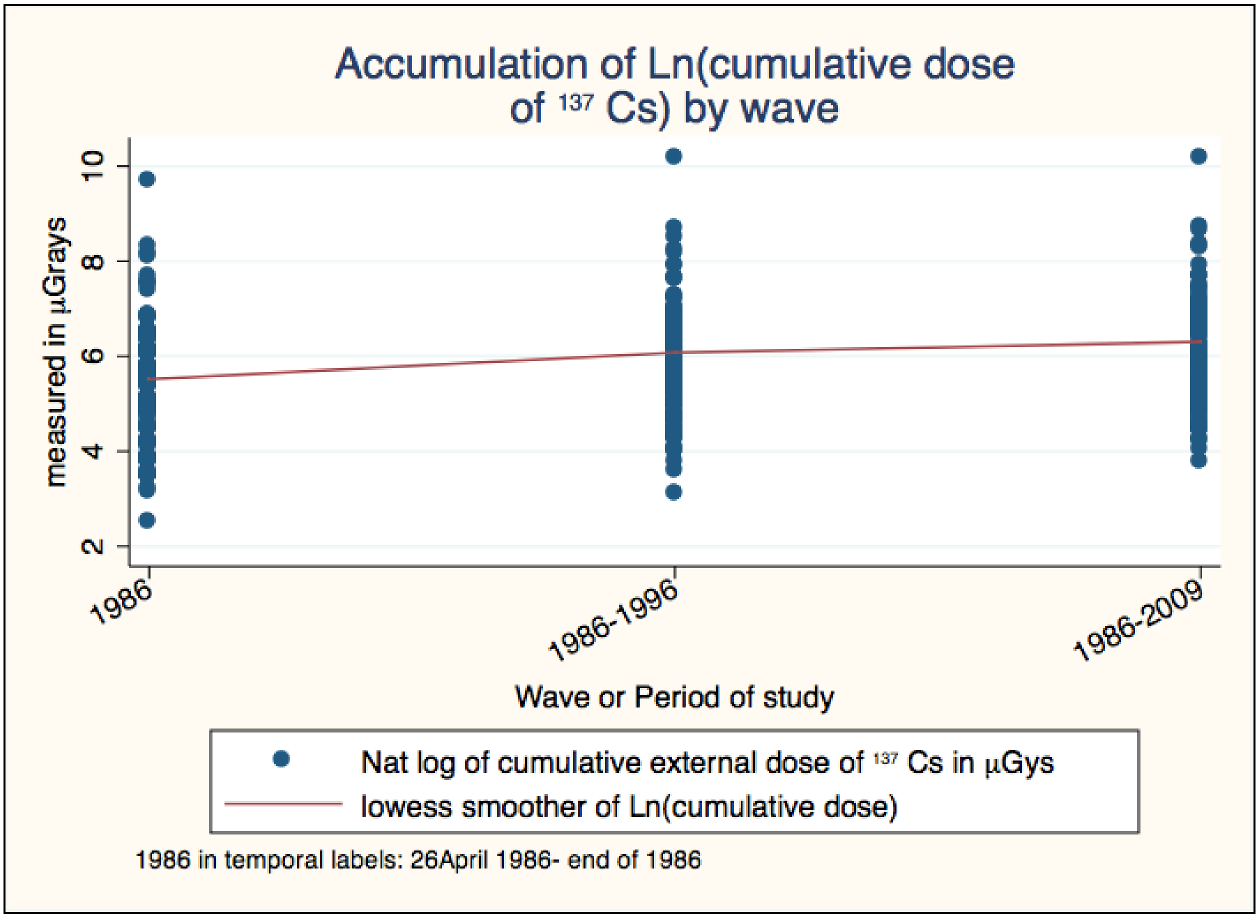
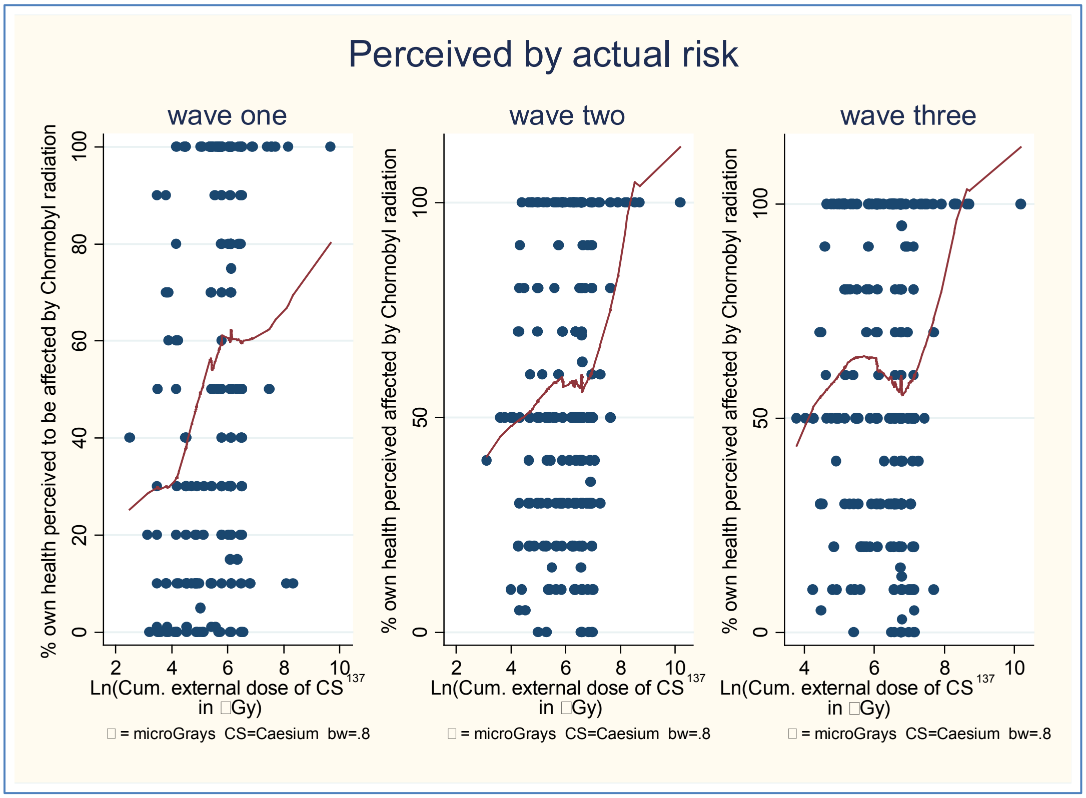


Figure 3: Perceived risk and reconstructed Cs-137 dose (actual risk)



The levels of perception of health risk and actual reconstructed radiation dose are plotted by waves in Figure 3. Despite the graphic congruence of perceived and actual risk factors, it is emphasized by the investigators that there is no radiological explanation for any association between the estimates of external dose from radioactive fallout and perceived risk. The magnitude of these doses is below any region where increases in biomedical effects could be differentiated from spontaneous incidence or those resulting from other natural sources of radiation.

However, the investigators suspect that the self-reported perceived risk associated with radioactive fallout twenty years after the Chornobyl accident may be influenced more by regionally-specific knowledge of radiation levels disseminated by media, public health and or scientific reportage. It is possible that over time people may have come to an assessment that their level of exposure was greater than they previously believed. People may be particularly susceptible to this amplification of risk when there is no way of clearly obtaining a precise measure of their actual exposure or risk. When in doubt, persons may not want to underestimate the risk for fear of that being overlooked in later reviews. They may want to incorporate this learned margin of error into previous recollections. Whatever may be the source, this finding is of great interest and will be pursued in forthcoming analyses of regionally-specific sources of disaster-related information dissemination.

4.5 Perception of Radiation Risk

Uncertainty about the physical radiation risks of the Chornobyl disaster has apparently led a large majority of the people to come away with formidable levels of perceived radiation risk of adverse health effects to themselves and their family. From our preliminary review of the data we observe that more than two-thirds of the sample report injury/impacted health as can be seen in the two frequencies tables immediately below (Tables 3, 4). Approximately 86% of the respondents in our sample claim to know someone with injury/impacted health from the radiation accident. These responses suggest that the disaster impact and the perception of injury to self and family is highly personal, pronounced, and something that these respondents experience as an active preoccupation.

Table 3: Frequencies of self-reported injury/impacted health from the Chornobyl accident:

Were you injured because of Chornobyl accident in 1986?	Frequency	Percent	Cum
• No	90	32.03	32.03
• Yes	191	67.97	100.00
Total	281	100	

Table 4: Frequencies of knowledge of others with injury/impacted health from the Chornobyl accident:

Was anyone you knew injured by the Chornobyl accident in 1986	Frequency	Percent	Cum
0. No	39	13.88	13.88
1. Yes	242	86.12	100
Total	281	100	

How pervasive is this perceived risk to oneself, the family, and neighbors at three points in time--specifically, 1986, 1996, and in 2009-2010? One indicator of this is the average percent that a person believes their health has been affected by exposure to Chornobyl radiation in 1986, 1996, and in 2010, shown below (Table 5). Interestingly, as this population cohort sample has aged, the average percent that people estimate their health to have been affected rises from 52.8% to 57.4% ten years later, to over 60% approximately 14 years later.

Table 5: Perception of Chornobyl radiation health risk by 3 time waves:

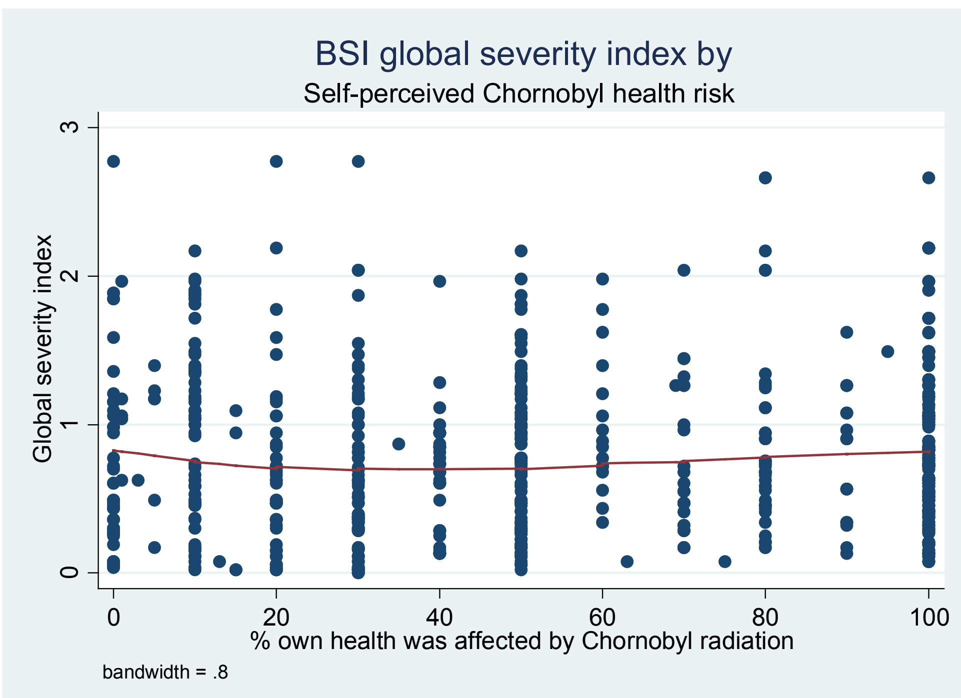
Percent my health was affected by Chornobyl radiation:

Variable	Obs	Mean	Std Dev	Min	Max
Wave 1 – 4/26/86 - 12/31/86	**265**	**52.79**	**38.08**	**0**	**100**
Wave 2 - 1/1/87 - 12/31/96	**267**	**57.47**	**33.18**	**0**	**100**
Wave 3 - 1/2/97 - 12/31/10	**268**	**60.09**	**34.20**	**0**	**100**

While this effect is not statistically significant, there is some suggestion that time may not work in favor of alleviating the suffering of people whose history included inadvertent proximity to this toxic accident. As time moves on, the average personal perception of radiation exposure may grow – an interim finding of great interest, which runs counter to long-term disaster outcome research for non-toxic events. Disaster-related anxiety typically shows decrease and attenuation over time (Norris et al, 2006). In addition, radiation-related concerns appear to be rather pervasive. Almost 61% of the Kiev and Zhytomir respondents reported a belief that most human cancers diagnosed in their respective oblasts developed from exposure to Chornobyl radiation.

In the current analysis we also examine the relationship between perception of risk and general population mental health functioning. Our findings show that the belief in radiation health risk does not appear to be related to levels of overall mental health distress, as denoted in Figure 4, which portrays the relationship between the BSI Global Severity Index (mental health index), and perception of radiation risk.

Figure 4: Population mental health index (BSI Global Severity Index) and self-perceived Chornobyl health risk



These indicators provide empirical indication of pervasive concern about the health risks of radiation exposure from the Chornobyl accident. To be emphasized is that this concern increases over time, and appears to not be significantly related to general mental health dysfunction. This phenomenon must be more clearly understood for radiation and other toxic accidents. In the current study, only an empirical test of the reality of harmful radiation effects could determine whether the radiation risk perception in the sample population is or is not warranted. Thus far, our preliminary reconstructions of cumulative external Cs-137 dose from the accident are below threshold levels for biomedical risk for this sample population. In pursuit of this question, our subsequent investigations will add reconstructed internal doses for Cs-137 exposure for further exploration of the relationship between perceived and actual risk.

4.6 Model Construction: Regression Partitioning Analysis

At this point in the preliminary analysis, we initiated a search for potential key variables that might explain or discriminate factors underlying the study sample's perception of Chornobyl health risk. For this purpose we utilized two statistical procedures: a regression partition analysis, or regression tree, and logistic regressions conducted respectively for the end of Waves one, two and three.

In searching for a structural frame of reference for our data, we recognized that the study deals with variables that exhibit non-normal distributions. Often, the variables are skewed or exhibit more or less kurtosis than found in a normal distribution. Hence, in our first statistical procedure, we resorted to a reference frame of "binary splits", consistent with the cognitive style in which people often make decisions, allowing us to for the time being to ignore the higher moments of these variable. A regression partition analysis, or regression tree, provides us with a sense of structure within our data. The partitioning at the trunk (root node) of the tree is similar to the application of a logistic regression to a dichotomously coded response variable.

We commenced this analysis with a binary split on the belief in Chornobyl radiation risk factor (Figure 5). We split this dependent variable at the 50% level. People who indicated that more than 50% of their health has been affected by

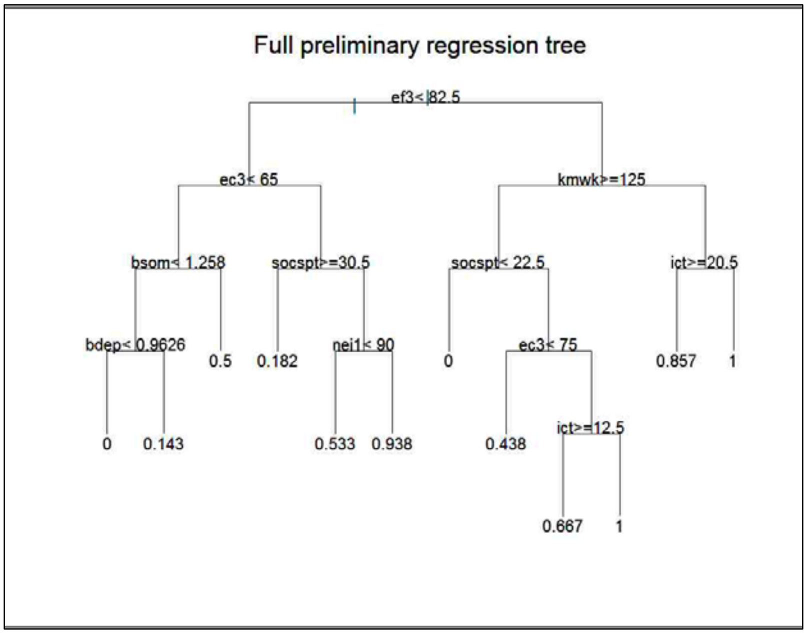
Chornobyl radiation received a one, whereas those who indicated that less 50% or less of their health was affected received a zero. We observed that many people who are not sure of what proportion was affected may select the median. For this reason, we used the threshold of over than 50% versus 50% or less. This provided the root node from which other splits stemmed.

Not surprisingly, the variable that explains most of this bifurcation of self-perceived and reported health risk from Chornobyl radiation is that of the *persistence* of effects of radiation now (which is abbreviated ef3 for efradw3 in our dataset). This variable has a threshold of 82.5 which forms the cut point on the scale, bifurcating the impact of this variable. At this nodal point in the bifurcation, two variable constellations emerge on the right and left hand of the tree, respectively: The left hand branch is driven by women in the sample who believe that macrosystemic economic problems are currently threatening to well-being (ec3). The right hand branch is driven by women in the sample who worked at long distances (kmwk).

Consider the left-hand "economic threat" side first. If the respondent's scale score on perceived economic jeopardy, ranging from 0 to 100, exceeded a threshold of 65, she tended to cope via available social supports (socspt). However, if the economic aspect of the threat was deemed less than a score of 65, somatic symptoms (bsom) seem to have been a more predominant preoccupation for this segment of the sample.

The binary split on the BSI somatic subscale at 0.9626 (almost one) on a scale ranging from -6.24 to 21.75 in our sample, revealed a mean of 0.96 and a median is -0.242. The cut-point for the binary split was 1.258. If the noted somatic effects did not reach this threshold, they could be explained by a binary split on the BSI depression score (bdep), suggesting more dysphoric psychological affect versus physical somatization.

Figure 6: Regression Partitioning Analysis, Regression Tree



However, if the women on the left-hand branch scored above the economic jeopardy threshold of 65, they coped primarily by relying on available social supports. If their score exceeded the 30.5 threshold on social support coping, there was a reliance on the neighbors for information (nei 1). The type of reliance depended on whether she scored above or below the 90 value on the neighbors during the first wave.

Consider the right-hand tree branches. If the respondent worked at a distance farther than 78 miles from Chornobyl (kmwk), she tended to cope less through social support. If she worked at a place closer than 125 km, she tended to be diagnosed with more medical diagnoses (ict), especially if they exceeded approximately 21 in number. Our sample exhibited coping scores from 11 to 33. If women in this sub-group coped more by social support by exceeding a threshold of 22.5, even though the mean was 25.595 and the median was 27, this was mainly explained by a binary split on economic problems (ec3 with a threshold here of 75). If their score was greater than 75 then they tended to have more than 12.5 medical diagnoses (ict).

This regression tree provides a sense of what variables on the simplest level can explain those immediately above them and closer to the root of the decision problem at hand: belief that Chornobyl radiation has impacted on personal health. To summarize: the belief that explains most of the decisional bifurcation is the highly related belief that Chornobyl effects still persist at the current time. *H*owever, there is a significant binary split at this level of the trunk between those who believe in threatening macrosystemic economic problems (left), and those who worked at a far distance from Chornobyl. On the main, those with "economic anxieties" on the left seem to have proceeded in a pattern of high social support utilization and neighbor dependence, or the manifestation of depressive and general somatic malaise. On the other hand, those on the right side of the decisional bifurcation were represented by women who worked at a far distance, depended less on social supports, were medically diagnosed with multiple conditions, and also experienced economic anxieties. These broad preliminary results seem reasonable as far as they go, in that they begin to shape constellations of explanatory variables that lead us towards understanding the population's still vibrant long-term perception of Chornobyl radiation risk. But now the question arises, can we begin to explain these results with closer resolution and explanatory power?

Given that the trunk partitioned tree (root node) is similar to the application of a logistic regression to a dichotomously coded response variable (i.e. belief in Chornobyl health risk), we now proceeded with a Wave by Wave analysis to see whether we could tease out of the impact structure of binary splits, a more temporal or dynamic structure that might reside within our data. In the section that follows, we will attempt to examine in greater detail the factors that contribute to the sense of perceived health risk stemming from Chornobyl radiation.

4.7 Model Construction: Hierarchical logistic regression

In moving forward with our analysis, we find a problem of missing data in the economic problems factors that are relevant to our study. In order to solve the problem, we utilize a procedure for data imputation which is based on a Bayesian statistical procedures (Little & Rubin, 1987).

Given that we used a form of random digit dialing, our sample was random. We thus make the working assumption that the data are also "missing at random." In other words, the observed data are a random sample of the whole sample, which includes the missing data. Therefore, we can use the observed data as a sample from which we can impute the proper values of the missing data. According to Little and Rubin (1987), regression or single (sample) imputation would lead to modeling problems. Regression estimation of missing values replaces the missing values with the mean of the variable. Unfortunately, this practice overlooks the effect this method has on the variance of the variable being augmented. Suppose we consider the variable, which has just undergone mean value replacement of its missing data, for inclusion in a regression model. Two effects of this protocol are noteworthy. First, we have more cases that are not missing and if we are employing only those observations with no missing data on any of the variables in the model (complete case analysis) we have more observations with which to find things significant and therefore more statistical power to detect smaller effects. Overloading that variable with means increases the proportion of the data that has one mean value, which in turn compresses the variance of the variable. If a relationship between our dependent variable and this candidate variable exists, the inadvertent variance reduction of the candidate variable will decrease the size of the standard error used in the t-test for the significance of the relationship. The result will be an increase in the size of the t-value, which will increase the probability of finding the relationship significant. The variable will appear more statistically significant than its true value, which biases the significance upward. With single (mean or regression) imputation in a complete case analysis, the model may become degraded by the inclusion of variables it should have excluded.

To avoid this pitfall, we need is a method of missing data replacement that retains a consistent estimate of the variance and therefore avoids such bias. Rubin introduced multiple imputation in the late 1970s as the proper way to solve this problem. As presented by Little and Rubin (1987), this method employs a Bayesian protocol that samples from a posterior predictive distribution by combining with a weighted average the prior distribution with the observable data. The weights accorded these components depend on the inverse of their variances (precisions). From the mean (θ) of M simulated datasets, they explain how the mean of the data to be replaced can be computed. To obtain the variance, he suggests decomposing the variance into the within- imputation variance and the between-imputation variance, respectively. These could be combined to determine the total variability. With = within-imputation variance and B_m = between-imputation variance for M simulations of the data. T_m = the total variance. Theta is distributed as a t distribution, with the number of degrees of freedom (df) of their respective dataset to simulate other datasets from which not only the mean value of the missing variables may be estimated; but can also preserve the variance of the variable by the use of multiple datasets. By resampling the posterior predictive distribution, a consistent variance estimate for the variable being imputed is assured. Because multiple imputation leads to less bias than conventional methods (Ibid, 45-62, 256), we perform our logistic regression analysis with multiple imputation.

Wave one model

Splitting our response variable (radhlw3) into two categories, those who are more than 50% certain that their health has been affected by Chornobyl radiation and those who exhibit less certainty, we formulate a new response variable called radrisk3. We first test main effects for significance and interactions among them for Wave one. We use this same outcome variable as we repeat the process for Waves one and two, and finally, for all Waves taken together. We employ robust standard errors to render the effects able to asymptotically withstand heteroskedasticity. The Wave one results may be found in Table 6. Although a pseudo-R square is not appropriate when multiple datasets are employed, we perform an auxiliary single dataset multiple logistic regression with the same binary dependent variable and the same sample size for each regression to ascertain what the Nagelkerke and McFadden's pseudo-R square would be. The reader should be cautioned not to consider these omnibus measures appropriately apply to the logistic regression performed by the multiple imputation. They do not. Rather, they are what would be derived had we performed a single logistic regression using the same variables. However, by sequentially accumulating significant main effects and interactions, we hope to ascertain whether we can extract which variables are fundamental to the explanation (retain their significance over time) and which variables are more period-dependent (exhibit changing significance dependent upon the waves being analyzed). As will be described below on page 35, for reliability assessment of our variable selection, we proceeded to check our procedure with two other algorithmically distinct statistical packages that were theoretically congruent with our primary statistical software suite. The discrimination among the variables may help us formulate the pathways to the Chornobyl-related health risk.

Table 6: Wave one Multiple Imputation estimate of logistic regression main effects and first-order interactions

```
Multiple-imputation estimates                   Imputations     =        210
Logistic regression                             Number of obs   =        186
                                                Average RVI     =     0.0000
DF adjustment:   Large sample                   DF:     min     =   1.20e+63
                                                        avg     =   1.19e+64
                                                        max     =          .
Model F test:       Equal FMI                   F(   8, 6.1e+65)=       5.65
Within VCE type:       Robust                   Prob > F        =     0.0000
```

radrisk3	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
medc1	.12809	.0606942	2.11	0.035	.0091315	.2470484
nei1	.0160591	.0062815	2.56	0.011	.0037476	.0283706
ef1	.0185996	.0056826	3.27	0.001	.007462	.0297372
txc	.0104765	.0060451	1.73	0.083	-.0013717	.0223248
hc	-1.485357	.5544351	-2.68	0.007	-2.572029	-.3986838
prbsc	2.313051	.8995616	2.57	0.010	.5499426	4.076159
bdep	.1603129	.0591247	2.71	0.007	.0444305	.2761952
ptsd	.0374629	.02102	1.78	0.075	-.0037356	.0786613
_cons	-5.625243	1.381638	-4.07	0.000	-8.333203	-2.917282

In Wave one, two environmental variables emerge as noteworthy. We observe a significant positive relationship between the Chornobyl radiation health risk and a belief that the effects of Chornobyl radiation pose a danger to their health (ef1), but the magnitude of the logistic regression coefficient is not large (b=0.019, p=.001). The other variable, the belief in the toxicity of radioactive material lasting for thousands of years (txc), only exhibits a slightly smaller coefficient with a more tenuous significance (b=0.011, p=0.083). Consistent with the belief in the harmful health effects of the Chornobyl disaster, is the noted utilization of medical services during this first Wave post-Chornobyl period (medc1, b=.128, p=0.03). As for the social milieu, the neighbors during Wave one (nei 1) are a significant source of information (b=0.016, p=0.011). Health problems are a concern, especially the number of medical visits for an existing condition (medc1, b=.128, p=0.035). That health problems interfere with social functioning is the most prominent response (prbsc, b= 2.313, p = 0.01) is not surprising; yet there seems to be an inverse relationship between health problems interfering with home care (hc), such as cleaning, maintenance, and the perception of Chornobyl health risk (b = 1.485, p= 0.007). Cleanliness and the reduction of dust in the home were public health directives offered to the exposed population for risk reduction. Psychologically, a positive association with depressive symptoms as assessed by the Basic Symptom Inventory, depression subscale and perception of Chornobyl health risk (b = 0.16, p=0.01) is evident. Also interesting is the quasi-significance of Post-Traumatic Stress Syndrome [PTSD] (b= 0.0375, p = 0.075). The value of the constant is very significant, but this coefficient is negative, suggesting that the mean level is not one of heightened risk (b = - 5.625, p = 0.000). This may stem from the fact that the average distance of the work of the female respondents in this sample was approximately 78 miles from the Chornobyl accident site.

Although the McFadden and Nagelkerke pseudo-R^2 (Long and Freese, 2006) squares are not provided by multiply imputed estimates, we performed the analysis on a single dataset and obtained respectively, 0.30 and 0.45. Thus the Wave one model correctly classifies 74.19% of the cases.

Wave two cumulative model

When we consider the significant and quasi-significant effects at Waves one and two (Table 7), we begin to obtain a sense of which risk factors may be consistently significant throughout the waves, which we call fundamental, and which may be period-dependent in their relationship to how the Ukrainian sample population perceived Chornobyl health risk since the accident in 1986.

Table 7: Waves 1 and 2 Multiple Imputation Logistic Regression main effects and first-order interactions

```
Multiple-imputation estimates                   Imputations     =        215
Logistic regression                             Number of obs   =        165
                                                Average RVI     =     0.0000
DF adjustment:   Large sample                   DF:     min     =   4.92e+63
                                                        avg     =   2.49e+65
                                                        max     =          .
Model F test:       Equal FMI                   F(  11, 1.4e+64)=       3.72
Within VCE type:       Robust                   Prob > F        =     0.0000
```

radrisk3	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
txc	.0050963	.006669	0.76	0.445	-.0079746	.0181672
hc	-1.840823	.5591583	-3.29	0.001	-2.936753	-.7448927
prbsc	1.73798	.7547291	2.30	0.021	.2587378	3.217222
bdep	.6579169	.2976773	2.21	0.027	.07448	1.241354
nei2	.0322758	.0084846	3.80	0.000	.0156463	.0489053
ec2	.0788721	.0251955	3.13	0.002	.0294899	.1282544
inthb	3.194467	1.061803	3.01	0.003	1.113372	5.275562
sxprbs	-1.230431	.6227896	-1.98	0.048	-2.451076	-.0097859
ec2Xec2	-.0006515	.0002385	-2.73	0.006	-.001119	-.000184
ptsd	.0609598	.0314565	1.94	0.053	-.0006937	.1226134
pXd	-.008946	.0048122	-1.86	0.063	-.0183777	.0004858
_cons	-7.810467	1.801745	-4.33	0.000	-11.34182	-4.279112

We call those variables that lose significance after the Wave transitions as period-dependent. The number of medical visits for an existing condition (medc1) fades from significance in Wave two. It is of interest to note that despite persistence of radiation risk perception (Table 5), high medical services utilization ceased to be a significant phenomenon in Wave 2, which began in January of 1987, only 8 months after the accident. The importance of accessing neighbors for radiation risk information for each respective time period (nei 1, nei 2, nei 3) will remain a fundamental phenomenon across Waves.

With reference to mental health and psychosocial functioning, depression (bdep) appears to remain fundamental and persistently significant over the three Waves. It appears thus far that those who believe their health and well-being were compromised by the Chornobyl radiation are also depressed. The relationship between Chornobyl radiation health risk and depression is positive and significant throughout the three Waves. Because PTSD did not reach significance [p = 0.075] during Wave one, but was quasi- significant during Wave two (b=0.061, p = 0.053) , PTSD is deemed somewhat new and period-dependent. It should be noted that while reconstruction of mental health symptoms assessed retrospectively for previous time periods lacks formal clinical validity, the retrospective self-report of these symptomatic experiences by respondents is of formidable interest, given their relationship to the protracted long-term perception of Chornobyl health risk also self-reported by the sample. Chronic depressive symptoms have been associated with compromises in both the immune system, and the inability to manage stressful contexts (NIMH, 2006, 2008, 2009, 2010).

In addition to the persistence of depression as a fundamental explanation for the perception of Chornobyl health risk, there were two other factors that retained fundamental importance over the three Waves. They are health impacting on social problems and functioning (prbsc)-a potential manifestation of depressive features, as is well-documented in the mental health literature; and home care (hc). Care and cleanliness in home maintenance remained negatively related to Chornobyl health risk throughout the study, probably revealing the effects of post-Chornobyl public health messaging in Ukraine, recommending daily domestic cleaning to reduce the risk of radiation carried by dust .

Other factors emerged as significant during Wave two that were period-dependent. Danger from the economic problems (ec2, $b = 0.079$, $p=0.002$) and its squared term (ec2xec2) ($b= -0.0007$, $p=0.0006$) were both significant, which suggests a slight downward curvature to this logistic relationship. This perception is consistent with the severe economic problems that lingered in Ukraine during the co-temporal post Soviet and post Chornobyl periods . The latter's importance is in its potential compounding stressor effect on a disaster-exposed population. A significant inverse relationship emerged between health causing problems with sex life (sxprbs) and belief in Chornobyl-related health risk. This finding may reflect a myth popularized in the post-Chornobyl era, that a small amount of radiation exposure from the accident fallout, could in fact enhance sexual performance . Nevertheless, this relationship only appears to emerge during Wave two.

Were we to assess the improvement in the fit of the models or the power of these models to correctly classify cases into a low or high risk group, we could obtain a sense of how much better the new model fits than the earlier one. The McFadden and Nagelkerke pseudo-R^2 for these variables on a single dataset were respectively, 0.342 and 0.503. For the Wave two cumulative model, this added R^2 is only about .04, whereas for the Nagelkerke only about .05. The Wave two cumulative model correctly classifies 82.21% of the cases, an improvement over the wave one model of 7.2%.

Wave three cumulative model

The Wave three cumulative model encompasses all time periods in the post-Chornobyl period up to the present time. Wave three cumulative analysis reveals three aforementioned fundamental factors contributing to the explanation of the Chornobyl related health risk: Depression (bdep), health problems interfering with social functioning (prbsc), and the negative coefficient of health problems interfering with “home care” (hc) (Table 8). The “home care” coefficient (b= -2.262, p = 0.004) remains significantly negative so the inverse relationship continues to hold between the perceived health risk and this home care. To the extent that respondents feel that their health has been placed at risk, the proactive behaviors of good “home care” appear to have reduced this risk perception. The depression coefficient remains significantly and positively (b = 1.386, p = 0.001) related to female Chornobyl risk perception, an apparently fundamental dyadic relationship in the current analysis, whose interaction must be further understood upon the completion of population sampling. In this cumulative Wave three model, ptsd now emerges as solidly significant, denoting the presence of Chornobyl-related traumatogenic mental health symptomatology that is still present 25 years after the event. While the symptom level is low and thus falls within a sub-clinical range (b=0.134, p=0.003), the finding holds instrumental validity given that the Wave three administration for the Mississippi PTSD scale was administered for symptoms experienced at the “present time”. Another factor of clinical interest in the Wave three model, is the solid and negative significance of the ptsd and depression interaction (pxd, b= - 0.021, p=0.002), a phenomenon that does not quite reach significance in Wave two. This would suggest a pointedly negative relationship between the two respective clinical states, indicating none of the co-morbidity often reported for the syndromes when assessed at clinical level ranges.

Table 8: Waves 1, 2, and 3 Multiple-imputed Logistic Regression estimates of main effects and first-order interactions

```
Multiple-imputation estimates                   Imputations      =        215
Logistic regression                             Number of obs    =        158
                                                Average RVI      =     0.0000
DF adjustment:   Large sample                   DF:     min      =   2.50e+63
                                                        avg      =   4.35e+65
                                                        max      =          .
Model F test:       Equal FMI                   F(  18, 3.9e+63)=       3.07
Within VCE type:       Robust                   Prob > F         =     0.0000
```

radrisk3	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
medc1	.1806288	.0973604	1.86	0.064	-.010194	.3714517
nei1	.0240006	.0078281	3.07	0.002	.0086579	.0393433
txc	-.013863	.010995	-1.26	0.207	-.0354129	.0076869
inthb	1.823779	1.059363	1.72	0.085	-.2525347	3.900094
hc	-2.26231	.9249594	-2.45	0.014	-4.075197	-.4494229
ill1	-.7853561	.4952697	-1.59	0.113	-1.756067	.1853547
prbsc	2.332599	.7892394	2.96	0.003	.7857179	3.87948
bdep	1.385518	.4123901	3.36	0.001	.5772479	2.193788
ec2	.0686089	.0315748	2.17	0.030	.0067234	.1304943
ef3	-.0155374	.0162022	-0.96	0.338	-.0472931	.0162184
ec3	-.0921802	.0359801	-2.56	0.010	-.1626999	-.0216604
rch3	.019557	.009379	2.09	0.037	.0011746	.0379394
nei3	.0208101	.0084999	2.45	0.014	.0041506	.0374697
ptsd	.1340072	.0444059	3.02	0.003	.0469733	.2210412
pXd	-.0210025	.0066939	-3.14	0.002	-.0341224	-.0078827
ec2Xec2	-.0007424	.0003003	-2.47	0.013	-.001331	-.0001538
txcXef3	.0004445	.0001949	2.28	0.023	.0000625	.0008264
ec3Xec3	.0010618	.0002956	3.59	0.000	.0004825	.0016411
_cons	-12.26219	2.778917	-4.41	0.000	-17.70877	-6.815617

In Wave three, several other explanatory variables re-emerge . Dependence on neighbors during wave one for information resurfaces as a significant but a small effect (nei 1, b= .024, p = 0.002), whereas Dependence on current neighbors for information appears significant as well (nei3, b = .021, p= 0.014).

Several Wave two risk factors re-emerge in this cumulative model. Belief in the jeopardy from economic problems exhibits some curvilinearity. The economic problems from Wave two (ec2, b=0.069, p=0.030) must be added to its significant squared term (ec2xec2 , b=-0.001, p=0.013. In this case, the impact of the squared term represents a tiny curved effect going from positive to negative, whereas when we consider the effect of the danger from current economic problems now, it has a predominantly negative slope (ec3, b=-0.092, p=.010) conjoined with a positive curvature (ec3xec3, b=0.001, p=0.001), equal in size to about a tenth of the magnitude of the downward slope. Economic anxieties thus seem to play some role in the female population's perception of Chornobyl health risks, probably contributing towards a cumulative stressors effect, and the multiple jeopardy that is so often seen in vulnerable population groups.

If we rely on those single model pseudo-R^2 to assess model fit improvement, we observe that the McFadden pseudo-R^2 increases to 0.433, whereas the Nagelkerke increases to 0.633. The wave three effects added about

0.091 to McFadden's R^2 and about 0.13 to the Nagelkerke R^2 explaining, as it were, the dichotomized Chornobyl health risk. However, the improvement in correct classification of the respondents improves 0.07%, raising the ability of the model to distinguish low from high risk respondents to 82.28%.

Assessing Variable Reliability

To assess variable "reliability" from our variable selection (Table 9), and thus create directives for relevant factor selection in our final analysis, we employed three different algorithms in different statistical packages. We used logistic regression with multiple imputation from Stata 11.2 and logistic regression with list-wise deletion from S-Plus 8.2 results. We obtained a full and a trimmed model. We use the trimmed models for comparison. We make an assumption that the robust standard errors would in general be a little larger than they are in models that test their results without them. Although we employ robust standard errors in our main models, our validation models supply ordinary standard errors, and their robust forms later. When a generalized linear model with a logit link and a binomial family is estimated by S-Plus, only t-tests are displayed.

Table 9 Variable selection and "reliability" in three models

Variables	Stata 11.2 multiple inputation		Autometrics 6.2 Multipath search		S-Plus 8.2 listwise deletion		Variable Reliability	
	b	p-value	b	p-value	B	T-value	# eqns signif.	% reliable
Dep. Var.	*Radrisk3 (binary)*		*Radhlw3 (continuous)*		*Radrisk3 (binary)*			
1.Constant**	-12.262	0.000	-	-	-9.875	-4.121	2	66.7%
2.Hmcare*			15.494	0.069	-1.970	-3.133	1.5	50.0
3.Econ1			-0.224	0.011			1	33.3
4.Effects1			-0.030	0.658			0	0.0
5. Neigh1***	0.024	0.002	0.178	0.003	0.023	3.040	3	100
6. Medc1	0.181	0.064					0.5	16.7
7. Ec2	0.067	0.030					1	33.3
8. Ec3**	-0.092	0.010	-0.005	0.982	-0.071	-2.000	2	66.7
9. Toxic	-0.014	0.207	-0.053	0.389	-0.014	-1.295	0	0.0
10. Rch3***	0.020	0.037	0.209	0.001	0.019	2.477	3	100.0

11. Ef3	-0.016	0.338			-0.023	-1.554	0	0.0
12. Nei3**	0.021	0.014	0.182	0.007	0.016	1.925	2.5	83.3
13. Bdep**	1.386	0.001			1.183	3.377	2	66.7
14. Ptsd**	0.134	0.003			0.116	2.962	2	66.7
15. Prbsc***	2.333	0.003	21.563	0.001	2.530	2.881	3	100.0
16. Fmprb			-2.217	0.769			0	0.0
17. Inthb	1.824	0.085					0.5	16.7
18. Illw1	-0.785	0.113					0	0.0
19.Ef3Xtxc***	0.0004	0.023	0.004	0.000	0.0005	2.596	3	100.0
20.HcXec3			-0.391	0.001			1	33.3
21.Pxd**	-0.021	0.002			-0.018	-3.047	2	66.7
22.Ec2Xec2	-0.001	0.013					1	33.3
23.Ec3Xec3***	0.001	0.000	0.004	0.036	0.001	2.857	3	100.0
Obs:	158 obs 215 imputations		158 obs 40 obs dropped		158 obs 40 obs dropped			
# vars sig05/ selectd	13/18=0.72		8/13= 0.62		11 /14=0.79			
Prop. Selectd	18/23=0.78		13/23= 0.57		14/23=0.61			
Prop. Sig	13/23=0.57		8/23= 0.35		11/23=0.48			
Notes: * variables with 50% or more reliability ** variables with 67% reliability *** variables with 100% reliability					T=1.96, p=.05 T = 1.645, p=0.1			

. The Wald tests that generate p-values are not sufficiently uniform in their likelihood when they are near zero, so that the significances may be biased. Rather than risk bias, S-Plus developers refrain from trying to present p-values. We insert a note to facilitate interpretation and use asterisks to indicate the more reliable of the candidate variables. We acknowledge that this method is not precise—for we have employed White semi-robust standard errors for our main models to fortify them against heteroskedasticity, while our validation models tend to estimate on the basis of ordinary standard errors. Indeed, we employ different statistical packages and even different coding of our dependent variables. For this reason, we apply quotation marks to reliability. Our objective is to ascertain which variables emerge as significant regardless of the variations in the algorithm or the statistical packages or the type of standard error being estimated.

To compare binary screening and theory-driven set-wise inclusion of variables with a general-to-specific algorithm, we compare those logistic regressions with Autometrics OLS using Hendry and Richard's (2007) general-to-specific approach.

Following Hendry and Krolzig (1999) and Doornik and Hendry (2007)in their appraisal of variable reliability, reliability percentiles were assigned to variables based on the proportion of the models in which each variable was statistically significant. For regression models to be valid, the assumptions on which they are based must be tested and adequately fulfilled. The user needs to include all of the explanatory variables that can potentially explain the dependent variable into the program. A general unrestricted model is thus formed with which Autometrics tries all possible exploratory paths formed by all combinations of different independent variables, subjects each combination (path) to a tests for each assumption. When an assumption is violated, the proposed combination fails the test and that path is terminated. Another path is pursued until a valid candidate model is developed. Candidate models are compared, with the most theoretically and variance encompassing are the ones selected, for combination into union models that are retested. Ties are broken with the Schwartz information criterion. Automatically, an optimal regression model is generated. Outliers and regime shifts can be automatically modeled in ways selected by the user. Autometrics can analyze data in blocks so it can handle dataset with more variables than observations.

We compare our model with its multiply imputed missing values to that generated by Autometrics, which drops the observations rather than imputes them. We are averse to dropping observations due to missing values and instead attempt to impute the missing values, although not all can be imputed. In a second pass on the same model, we force the inclusion of the main effects in the model after Autometrics selects interactions that require their inclusion, thereby assuring proper specification of the interaction. We assign the variable 0.5 points for being significant at the 0.1 level and a value of 1 for each model in which it appeared statistically significant at the 0.05 level. After tallying the variable total, we divide it by the total possible and arrive at reliability percentage. Those variables selected in two or more of our models, we star in the first column of

Table five. The reliability score is based on the proportion of the three equations in which that variable emerges as statistically significant.

Were the variables sorted according to their reliability, we would find that five of these variables are always significant. Among them are dependence on social neighbor networks for Chornobyl information, the % belief that pollution now is related to Chornobyl, health problems interfering with social life, as well as the square of the danger posed by economic problems at current time. Apart from the constant, there are seven other variables that are significant in 50% or more of these models. They include health problems interfering with home care, danger from current economic problems, dependence on social neighbor networks for Chornobyl information, depression symptoms, PTSD symptoms, the interaction between PTSD and depression, the danger posed by economic problems in wave two and wave three, among others. The full list may be found in table five below. From this assessment, we may develop an idea about which variables to use as candidates in a path model of the etiology problems reported by our respondents. Because of its advanced capabilities, we compare our variable selection to that of Autometrics (Doornik & Hendry, 2007) to facilitate inclusion of important variables in our models. This program can thus make the data mining of large datasets in short periods of time possible, even in psycho-social-medical sciences.

5. SUMMARY and DISCUSSION

The current paper presents initial analyses of the Ukrainian study sample's 1) cumulative external dose exposure to the Chornobyl radiation source term: Caesium-137, and 2) long-term cognitive, psychosocial, health related, behavioral and mental health outcomes in a random population (N=281) of Ukrainians exposed to the Chornobyl nuclear plant disaster in 1986. A particular focus of interest is the relationship between physical radiation risk (Cs-137 dose exposure), the cognitive perception of radiation risk, and multiple long-term outcomes.

Our interim results describe a population whose perception of both personal and family radiation health risk remains high at 25 years post radiation accident.

Atypical for disaster outcomes, the experience of disaster-related jeopardy to self and family health has not attenuated across time since the accident. The perception of Chornobyl radiation risk on health has in fact steadily increased since the time of the accident. This finding may be a potential contribution to the knowledge base of long-term outcomes for large, environmentally compromising *toxic* disasters. The perception of risk for toxic events may constitute protracted, long-term responses, given the amorphous, intangible nature of many toxins, and the inability to clearly define the end-point of exposure.

In order to understand the pivotal role of cumulative radiation dose exposure as it relates to the population's perception of radiation risk, the current study reconstructed estimated cumulative external exposure rates to Cs-137 for each respondent. Applying factors of residence, occupation, age cohort and geographical dosimetry rates for Cs-137 to established formula norms for estimated exposures (Likhtarev et al,1992), the study yielded a cumulative radiation dose rate from 1986 to the present that was far below established thresholds for clinical health risk (see Fig. 1). This finding is consistent with other recently reported cumulative radiation dose exposures and radiation risks for Ukrainian population.

While physical jeopardy for radiation-related disease was thus established as low for the sample population, respondents' perception of health risk was found, nevertheless, to be related to their radiation dose exposure rate (see Figure 3). Our final analysis will focus attention on the broad range of factors that could potentially mediate this phenomenon. However, at this time, Investigators conjecture that this finding describes a population that has in some way followed disseminated comparative external radiation dose levels for their respective townships and settlements, and responded as a lay/non-scientific population group to relatively higher levels of environmental radiation in their areas, with respectively higher levels of risk perception. We will ambitiously explore the complex sources of radiation fallout information for our sample and its influence on risk perception across time since the nuclear accident. For example, our current findings show consistent evidence of radiation hazard information being communicated by social neighbor networks. Social rumor propagation was a highly prevalent form of disaster-related information dissemination in Soviet Ukraine, given the government's initial policy of accident denial.

Preliminary findings show that the formidable levels of radiation risk perception in the sample were not statistically related to a measure of overall mental health distress (BSI, Global Severity Index, Figure 4), and thus the potential distortions that can arise from such states. This may be interpreted as a population whose protracted concerns about radiation-related health outcomes, are somehow being contained by functional coping mechanisms. Further attesting to the current status of this disaster-exposed Ukrainian sample, the high perception of health risk was found to not be functionally impacting on paid employment or family role functions as assessed by the study's standardized instruments.

Given the higher preponderance of females in the current interim sample, complex statistical procedures used to investigate the explanatory and discriminating factors of our outcome measure: perceived Chornobyl health risk were applied only to the female cohort (n=158). These were a regression partitioning tree, and hierarchical logistic models for each of 3 respective post-Chornobyl time Waves: Wave one (April 26,1986-Dec.31,1986), Wave two (Jan.1,1987- Dec.31,1996), and Wave three (Jan.1,1996- Dec.31,2010).

The regression tree yielded an array of relevant factors that may guide us towards factor groups or pathways in the final analysis. There is a bifurcation among women who believe (Figure 7, left) that radiation has both impacted on health and persists in its impact at the present time: On the one hand there is a group whose radiation risk perception was driven by the compounding impact of macrosystemic economic problems. Interestingly, those who perceived economic jeopardy above a defined threshold, tended to cope via available social supports and reliance on social neighbor networks. Those below the threshold formed a separate group characterized by self-reported somatic preoccupation and depressive symptoms. On the opposite side of the regression tree (Figure 7, right), are women whose radiation risk perception was partially explained by distance from work : those working at far distances from Chornobyl tended to cope less through social supports. Those working at closer distances tended to have a higher number of medical diagnoses.

In the attempt to investigate these explanatory variables at a greater level of discrimination and temporal influence across the 25 year post-disaster period, we proceeded with a 3 Wave post disaster logistic regression procedure. This procedure was initiated by first imputing missing data according to a Bayesian protocol. These analyses yielded both a series of explanatory risk factors that were consistently significant across the Waves, which we called fundamental; and a group of risk factors that were Wave- specific, or period-dependent in their relationship to the Ukrainian female population's perceived Chornobyl health risk since the accident in 1986.

Self-reported depressive symptoms emerged as a fundamental risk factor across the 25 year post-disaster period, as did the report of health impacting on social functioning - a potentially dynamic constellation that is apparently related to heightened radiation risk perception in this sample. A similar depressive-somatic spectrum grouping was seen in the regression tree just described above. It is unclear from this analysis however, whether these depressive and social inhibition features represent a predisposing pre-morbid , albeit sub-clinical reactivity to disaster events as reported in the disaster literature (Norris et al,2006), or a unique long-term sequela of the radiation accident per se. Final analysis of the completed sampling should allow us to conduct discriminatory explorations of these phenomena. Approaching significance in Waves one and two, and reaching significance in Wave three, are low levels of Chornobyl-related post-traumatic response in a very small segment of the population. This will be an important finding to follow at the completion of sampling. The international literature cites an average of xx% of a population will manifest long-term traumatic sequel post-disaster.

Also fundamental to the perception of Chornobyl health impact was that home care activities consistently mitigated radiation risk perception across all time Waves (see Tables 6,7,8). In the post-accident period, public health and media directives emphasized the retention of radiation particles in common dust, thus offering the exposed population a proactive and self-directed mode of "exposure prevention" through home cleanliness, which is apparently still being utilized to constructive effect. In the psychosocial domain of functioning for each respective Wave, use of social neighbor networks emerged as a protracted and fundamental source of disaster-related information for the Ukrainian sample population.

Period-dependent explanatory factors appeared to reflect temporal/historical consistencies with both post-disaster public messaging, and socio-economic phenomena: These were the high frequency of medical visits just after the Chornobyl event in Wave 1, and the high perception of economic jeopardy during the depressed post-Soviet Ukrainian economy in Waves two and three.

Finally, as discussed in the section just above, we employed three different algorithms in different statistical packages for the purpose of assessing and testing the variable "reliability" from our variable selection. Our objective was to ascertain which variables emerge as significant regardless of variations in algorithm or statistical software. Our assessment yielded a satisfactory profile of very similar variables that had emerged as fundamental factors across the three Waves of our original analysis. We have begun to pave the way towards our final analysis.

Our conclusions are guarded given the interim nature of the current smaller sample analysis, however Investigators are most impressed with the clinically sub-threshold cumulative caesium-137 exposure for our sample, especially as it is coupled with the finding of population's unattenuated perception of radiation risk at 25 years post-disaster. Of added interest to this complex phenomenology is the surprising mental health and psychosocial function status of this sample, which despite its exposure and health jeopardy concerns, does not manifest significant or pervasive clinical compromises in broad general functioning. This is an indication of what might be considered a currently resilient population of radiation disaster survivors.

Note: For variable selection, we have used OxMetrics (Autometrics) 6.2 and S-Plus 8.2. For our regression tree, we have used S-Plus 8.2 and for the hierarchical logistic regression we have used Stata 11.2 and S-Plus. Multiple imputation was performed with Stata 11.2. We remain grateful to those at Insightful, Tibco, OxMetrics, and StataCorp for their excellent programming.

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