File Attachment #102
Hypothesis One, Part One: Findings Relating to Associations between Reconstructed External Dose of ^{137}Caesium and Psychological Sequelae of Chornobyl (Hypothesis 1)

DRU: Modeling Nuclear Disaster Risk: The Effects of Perceived Risk and Radiation Exposure on Post-Chornobyl Psychosocial and Health Behavior Outcomes in Ukrainian Residents
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Contents

1 Introduction

In this section of the report, we discuss 24 hypotheses formulated within the grant proposal and the methods by which we test those hypotheses. In this section we address hypothesis one, which states that radiation does directly and significantly explains and hence predicts self-reported health as measured by the Nottingham health scale. Our sample, consisting of 340 male respondents and 363 female respondents was obtained by a process of random digit phone number selection. Thus, the sample was designed to be a probability selection of the population. In this section, we focus on three primary domains of the first part of the Nottingham health profile–namely, those domains which pertain to pain, sleep, and energy level. In so doing, we examine the dose-response relationship to them. The average cumulative dose of Caesium 137 is measured in milliGrays. Caesium 137, which is sometimes abbreviated as ^{137}CS or CS^{137} has a half-life of approximately 30 years. This isotope is used as the indicator because its deposition can be considered a general indicator of the kind of radiation deposited under circumstances that are worthy of note. It is an isotope that could conceivably still be a matter of concern, unlike Iodine 131, which has a half-life of about 8 days. This dose is the amount of the radiation that the body has been exposed to by where and how the respondent has reported his living, working, drinking, eating and other pastimes during the study period.

The second part of the Nottingham health profile pertains to general activities of life– more specifically, to paid employment, home care, problems with the family at home, problems with the sex life, problems with the social life, impacts on interests and hobbies, and impacts on vacation plans.

Because one of the objectives is to discover the key relationships whose configurations forms the etiological pathways through which dose effects the psychological sequelae of Chornobyl, we divide these effects into direct, indirect, and total effects. For this reason, when we call an effect a direct effect, we refer to it not as a direct as opposed to an inverse relationship, but rather as direct as opposed to an indirect effect. A direct effect can be positive or negative in its relationship. It need not be a positive one. However, it must be statistically significant to be empirically based.

Therefore, we operationalize the Nottingham health profile by encoding the terms and weighting them as they are prescribed by the authors of that system of subscales. For reasons to be explained psychologically, we focus on the subscales deemed to be most important to our objectives in determining the effects of consequence. The Nottingham pain subscale extends from 0 to 82.75, regardless of gender. The male mean on this scale for our sample is 10.18 and the female mean is 18.01. The standard deviation for the males is 16.45 and for the females it is 22.33. Zero is a valid score on this scale and 207(60.88%) of the 340 males report a score of 0, whereas 158 (43.53%) of the 363 females report a score of zero. For the males, 67.05% report a score of 9.99 or less. For the females, 67.77% report a pain score of 23.37 or less. Both male and female distributions have a positive skew. The male skewness is 1.75 and the female skewness is 1.15. In short, 51.92% of all respondents report a score of 0.

In general, this section pertaining to part one of the Nottingham is organized as follows. For each of the pain, sleep, and energy level subscales, we will examine the relationship for men and women in each of three waves. We will examine the direct effects from a a linear regression in part one, potential moderators from a first-order interaction analysis, and potential mediators from a preliminary structural equation model. We will explain any moderation that could affect the direct effect

2 DIRECT EFFECTS ON MENTAL HEALTH AND PHYSICAL HEALTH

2.1 H1: Radiation dose directly significantly predicts self-reported health as measured by Nottingham Health Scale

The Nottingham health profile consists of two parts. We examine the subscales of the Nottingham that related to physical and psychological health. The first part consists of a set of subscales, weighted and a second part relates to impact of health problems on the lives of the respondent. We address the part 1 subscales relating to energy level, pain, and sleep. Part 2 of the Nottingham pertains to areas impact of the health problems suffered by the respondent–consisting of paid employment; home cleaning, cooking, and repairs; social life ; causing problems with family members at home; sex life; interests and hobbies; and vacations.

We can examine the relationship to be tested in several ways. First, we can examine the zero-order relationship, without the use of other covariates. This might provide us with a sense of the total relationship and as a point of departure.

These phenomena, represented by these subscales, do not exist *in vacuo*. They arise in real situations in which a number of potentially confounding influences also exist. We have to partial out or control in order for alternative effects effects to properly arrive at an understanding of the nature of the targeted relationship to be tested. We will endeavor to include the principal confounders in a regression analysis in order to properly the relationship targeted by our hypothesis. We do this in several ways. We can include them as other independent covariates in the regression and partial out their competing or enhancing effects. We can test interactions to determine whether there are joint relationships over and above the individual direct relationships that reinforce or suppress the strength of the main effect, resulting in a moderated total effect. Alternatively, we can test their zero order relationships as mediating relationships to determine whether there are intervening or mediating variables which may be necessary for an indirect effect to occur. If an indirect effect is coupled with a direct effect, the combined effect may be more or less than what an individual direct effect might be.

Therefore, at this point we test alternative paths to determine whether there might be a mediator that could influence the direct effect. If a variable intervenes between our endogenous pain variable and our average cumulative reconstructed dose, two links to the indirect relationship are established. The first link proceeds from the dose to the mediating variable, and the second link proceeds from the mediating variable to the pain subscale. To properly explain this point, we have to assume that the regression coefficients describing the sign, magnitude, and significance of those relationship links are the same. That is, we assume that if one comes from an ordinary least squares regression, the second regression will also come from the same kind of a regression analysis. We cannot have one link coming from a classical ordinary least squares regression and another link coming from a logistic regression for those regression coefficients would not be the same. If they are not the same, they could not given our objectives multiply one by the other and come out with a product that would be comparable to an indirect effect generated by two OLS regressions. When a mediator or intervening variable exists through which an indirect effect is passed, the strength of the indirect effect is computed by multiplying the coefficient representing the first link with the coefficient representing the second link.

In a path analysis, we have to determine which effects are direct effects by determining which other effects might be indirect effects. The total effect is the sum of the direct, indirect, and spurious effects. By estimating the direct and indirect effects, we may add them to obtain the total effects. However, there are two types of spurious effects. They consist of those that we know about and those that we don't know about.

The spurious effects that we know about can be computed by subtracting the direct and indirect effects from the zero-order relationship, which we use as our starting point. What is left over is the spurious effect that we know about.

The spurious effect that we do not know about can be any unsuspected antecedent variable that is related to our supposedly exogenous cumulative dose and our presumed endogenous pain subscale. However, if there is an antecedent variable, unbeknownst to us, our presumed exogenous dose is no longer exogenous but predetermined or influenced by that unknown prior "cause.". Such a situation would endow our observed relationship with an uncertainty that might not be possible to estimate. It would also preclude us of being 100% certain of much of anything.

Our objective is to minimize any kind of specification error we can by including all of the potentially related variables and thus forming some sort of general unrestricted model as a starting point. For this reason, we add covariates that could provide alternative plausible explanations to the relationship we are testing to control for their effects [1, 25-26].

Among the variables we employ as confounders are the socio-demographic characteristics of the respondents, the computed geodesic distance in miles from the accident site, as well as local measures of support that the respondents might experience. As for the sociodemographic characteristics we employ martial status, the number of children for women, and income sufficiency for various levels of quality of life. We also control for perception of risk to oneself of the Chornobyl related health threat in addition to some function of the distance of the respondent at the time of the accident from Chornobyl.

2.2 The Dose-Response relationship in three waves

We will perform this analysis with separate models for males and females prior to comparison of them. Before we decide how to analyze these response patterns, we graph the endogenous variables of the Nottingham Part I scale. The purpose of the graph is to provide a visualization of the nature of the relationship before we commence our analysis. We will graph this relationship for men and women in three waves to see how it differs between men and women and to see how it evolves for each gender over time. When we examine these graphs, in Figures 1 through 6, we observe that as time passes the relationship tends to attenuate. For the males, the later graphs depict more of a decline in the slope, whereas for the females, the graphs depict more of a leveling off of the relationship. The relationship becomes a little more diffuse over time, but this is not as apparent as the attenuation. The first of these subscales we consider is male report of the Nottingham pain subscale, found in Figure 1. If we examine the pain reported by the males and females over the three waves of the study, we can observe they are not constant over time.

From Figure 1 we observe that the pattern of rise and leveling off of the

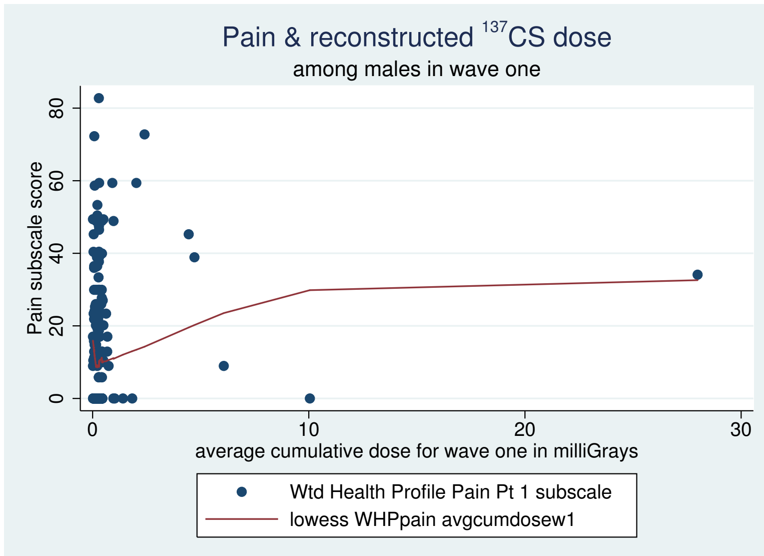

Figure 1: **Male Pain and reconstructed cumulative dose in wave 1**

relationship between the reported male pain over time. In 1986, wave one, the pattern exhibits a leveling off at the level of approximately 10 milliGrays of average cumulative dose of ^{137}CS. In wave two, this turning and the relationship appears even more sharply but at about 13.5 milliGrays. After this turning point the slope assumes the shape of a negative decline. Within wave three, slope increases until approximately 14 milliGrays, whereupon it also sharply turns into a linear decline.

From the male analysis, we observe that the relationship that we will be analyzing does not appear to have a linear form. It is a lowess graph so the line running through it is a least squares line within a given bandwidth. In order to deal with this structure, we will use regression splines to accommodate the change in direction or slope. We will generate these as part of the multivariate adaptive regression spline package called MARS [2] developed by Jerry Friedman and marketed by Salford Systems in San Diego, California. MARS automatically constructs basis functions that minimize the loss function applied to the analysis. Where they turned out to be statistically significant improvements for our analysis that enabled us to model hockey stick shaped forms of the relationship between the endogenous variable and our independent variables, we employed these regression splines to facilitate modeling delayed or threshold type associations. We define these functions as they emerge as statistically significant predictors in our analysis. More often than not, they entail a recentering of our existing variables that enable us to analyze otherwise nonlinear relationships.

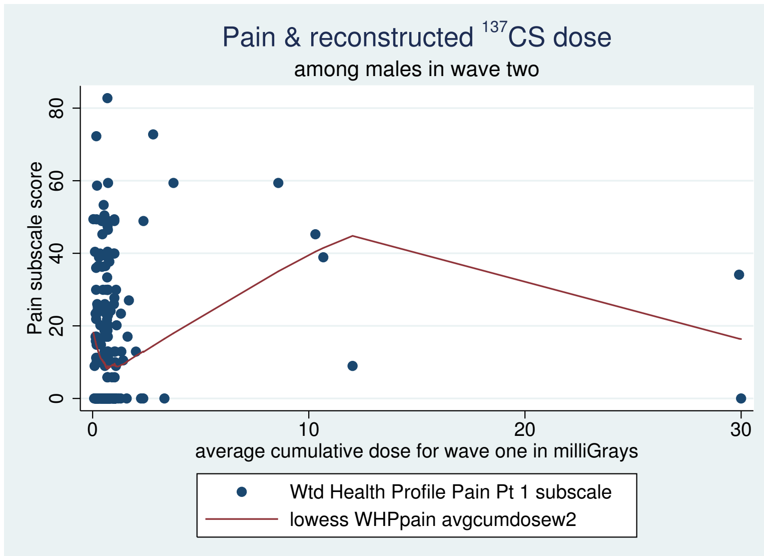

Figure 2: **Male Pain and reconstructed cumulative dose in wave 2**

Because there is no summary score for the Nottingham we have to use the subscales. We take five subscales from Part I and 7 subscales from part 2 and address salient aspects of a matrix of relationships that summarizes prominent aspects of the relationships. First, we want to know whether there exists a significant statistical relationship between reconstructed dose and the subscale of the Nottingham being considered. Second, we want to know whether this relationship is moderated or mediated by other variables. Otherwise, we cannot know for sure whether any relationship really exists. It may be that there may be a zero-order relationship but not a relationship where other covariates likely to confound the situation exist. Therefore, we test three types of relationships. Zero-order direct relationships, moderated relationships, and mediated relationships to discover under what circumstances we might find the dose-response relationship for which we are searching.

In the female analysis, we also have to examine the nature of the endogenous variables. As we do, we will notice a difference in the pain pattern. Instead of reaching a peak at which the sign of the slope undergoes a change in the downward direction, we observe that it merely declines in magnitude rather than in its directional sign.

We can get a sense of how this changes if we employ basis functions or regression splines to facilitate our analysis. We use Multivariate Adaptive Regression splines (MARS) to identify nonparametric a set of regression splines based on basis functions that turn out to be statistically significant predictors. MARS

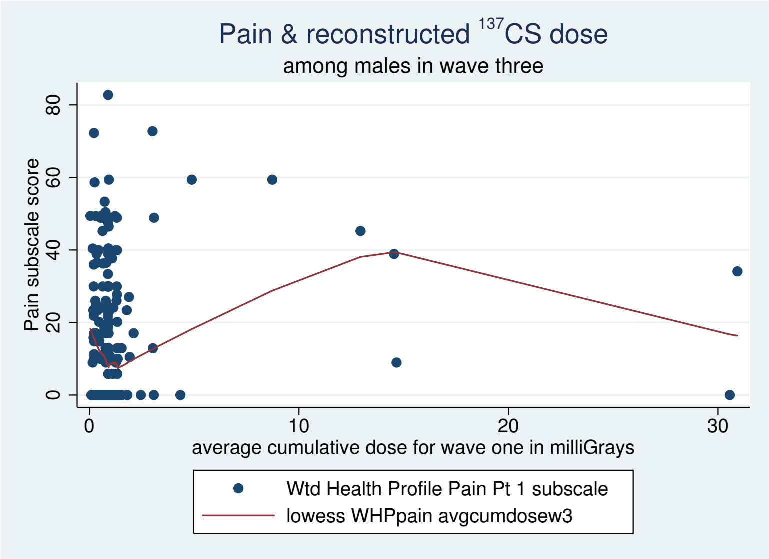

Figure 3: **Male Pain and reconstructed cumulative dose in wave 3**

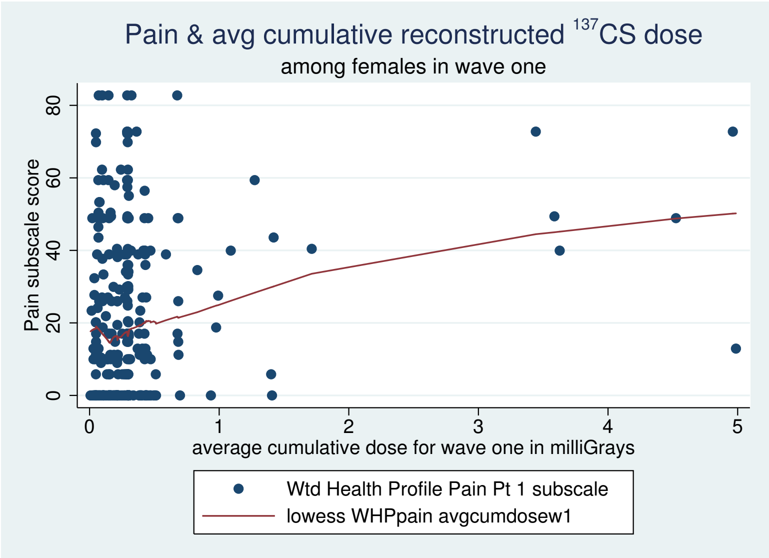

Figure 4: **Female Pain and reconstructed cumulative dose in wave 1**

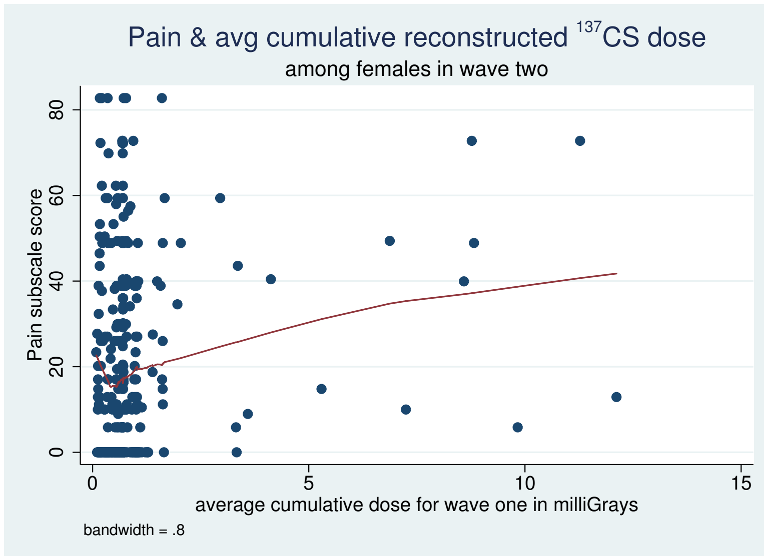

Figure 5: **Female Pain and reconstructed cumulative dose in wave 2**

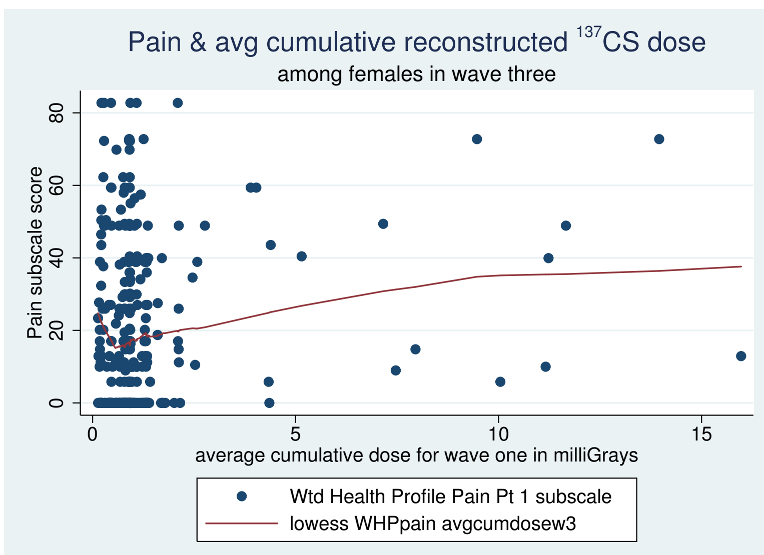

Figure 6: **Female Pain and reconstructed cumulative dose in wave 3**

3 Hypothesis 1 part 1

4 The Dose-Pain relationship

In this analysis we explore the dose-response relationship between reconstructed dose of ^{137}Caesium and pain, sleep, and energy level. To determine which are the direct effects, as opposed to indirect effects, we have to determine what effects are the indirect effects and which effects are the moderating effects.

With a view toward identifying the principle parts of our path analysis, we commence with a study of the dose psychological response relationship of pain. We divide this study into three waves. Wave one covers the time of the accident until the end of the 1986 year. Wave two extends from January 1, 1987 through December 31, 1996, and wave three runs from January 1, 1997 until the time of the interview in 2009, 2010, or 2011. However, in order to uniformitize the end-point, we ceased dose reconstruction as of January 1, 2009. We analyze men and women separately within each wave. Altogether, we have six analyses to deal with each hypothesis.

We commence with an analysis of the zero-order effects of average cumulative dose of ^{137}Caesium on pain as measured by the Nottingham health profile. This is not merely an academic exercise. It is a first part of a path analysis in order to determine the size and direction of the total effect. We commence with a zero-order test for the relationship between reconstructed cumulative dose for wave 1 and pain. For males, the measure of pain is statistically significant in a regression of pain on average cumulative dose in wave 1 only ($b = 1.112,\ se = .3785,\ t = 2.93,\ p > |t| = 0.004$). When we control for potentially confounding factors such as age, educational attainment, marital status, family size,employment status, occupational status, income sufficiency, the perception of Chornobyl related health risk to oneself, as well as the residential distance to the Chornobyl plant the relationship retains statistical significance ($b = 1.032,\ se = .332,\ t = 3.11\ p > |t|\ = 0.002$). In waves two and three, this relationship did not appear to be statistically significant.

As for females, a different story emerges. Regardless of the wave, a statistically significant relationship emerges between the reconstructed cumulative dose through the specific wave, on the one hand, and pain as defined by the Nottingham weighted health profile, on the other. Table one reveals the ordinary least squares regression coefficients and their robust standard errors in parentheses below for the average cumulative dose of ^{137}CS at the time of each wave.

Table 1: Effects of reconstructed dose on female pain from ordinary least squares regressions.

Zero-order regression coefficients of reconstructed dose on female pain

	wave1	wave2	wave3
avgcumdosew1	7.950***		
se	(2.295)		
t	3.463		
p	0.001		
avgcumdosew2		2.451*	
		(1.017)	
		2.410	
		0.016	
avgcumdosew3			1.794*
			(0.787)
			2.278
			0.023
Constant	15.344***	15.816***	15.856***
	(1.377)	(1.444)	(1.466)
	11.141	10.953	10.818
	0.000	0.000	0.000
adjR^2	0.036	0.020	0.017
bic	3281.569	3287.288	3288.427
N	363	363	363

* p<0.05, ** p<0.01, *** p<0.001

Zero-order regression relationships are virtually *in vacuo*. We endeavor to make the model more realistic by attempting to control for potentially confounding effects of alternative plausible explanations by including socio-demographic and and sometimes psychological factors. We also introduce such covariates to minimize model specification error. When we add these realistic explanations, the results can change.

We enter a full model, which controlled for age, education, occupational status,and income sufficiency, and none of these turned out to be significant predictors. Consequently, we trim them from the model. When we re-estimate the trimmed model, we obtain a result similar to that of the zero-order relationships. In that only the first wave dose-pain relationship remains statistically significant, we obtain the same result, shown in Table two below.

Other than the constant in the regression model, the only statistically significant variable in all three equations and that is a basis interaction generated by MARS that includes a basis function, called $bfmPain15 = max(0, 21918 - illw3) * bfmPain2$ with $bfmPain2 = max(0, 21935 - BSIsoma)$ The $Illw3$ variable is a count of the number of illnesses the respondent reported in wave three and the $BSIsoma$ variable is a Basic symptom inventory somaticism subscale score [2]. Apparently, voluntary employment is associated with pain as well in waves one and two (emplw14 and emplw24). By wave three, the percent of the pollution due to Chornobyl (radchw3) is also associated with male pain.

There are a few variables that are statistically significant in two of the three models. One of these is another regression spline generated by MARS which is called $bfmPain2 = max(0, 21935 - BSIsoma)$, and this is a recentering of the somatic subscale of the Basic Symptom Inventory [3, 115-127].

Table 2: Main effects regression models of reconstructed dose on male pain

	wave1 1986	wave2 1987-1996	wave3 1997-interview
age	0.073	0.020	0.017
(in years)	(0.095)	(0.076)	(0.089)
	0.442	0.796	0.850
emplw12	3.333		
(full time	(4.353)		
in 1986)	0.444		
emplw13	2.631		
(part time	(4.056)		
in wave 1(1986)	0.517		
emplw14	64.343***		
(voluntary)	(6.168)		
	0.000		
emplw15	9.097		
(retired)	(5.361)		
	0.091		
emplw16	4.286		
(unemployed)	(4.225)		
	0.311		
radhlw1	-0.031		
(hlth threat to	(0.038)		
oneself in 1986)	0.408		
radfmw1	0.024		
(hlth threat to	(0.036)		
family in 1986)	0.512		
radtlw1	0.054		
(lifetime exposure)	(0.031)		
	0.086		
radchw1	0.030		
(prop pollution	(0.031)		
due to Chornobyl)	0.333		
havmil (residentl	0.002	0.002	0.001
distance frm Ch)	(0.007)	(0.007)	(0.006)
	0.725	0.776	0.848
bfmPain2	3.833**	3.033**	2.005
(basis func)	(1.230)	(1.157)	(1.204)
	0.002	0.009	0.097
bfmPain15	-0.000***	-0.000***	-0.000**
(basis func)	(0.000)	(0.000)	(0.000)
	0.000	0.000	0.006
avgcumdosew1	0.798**		
(cumlative dose	(0.279)		
in wave one)	0.004		

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emplw22		6.400*	
		(2.535)	
		0.012	
emplw23		6.961*	
		(2.891)	
		0.017	
emplw24		69.088***	
		(3.667)	
		0.000	
emplw25		10.609*	
		(5.078)	
		0.037	
emplw26		3.246	
		(3.389)	
		0.339	
radhlw2		0.024	
		(0.026)	
		0.363	
radchw2		0.052	
		(0.032)	
		0.104	
radtlw2		0.035	
		(0.031)	
		0.250	
avgcumdosew2		0.438	
		(0.333)	
		0.190	
emplw32			-0.859
			(2.274)
			0.706
emplw33			3.900
			(2.955)
			0.188
emplw34			-0.172
			(2.800)
			0.951
radhlw3			0.028
			(0.032)
			0.382
radchw3			0.092**
			(0.031)
			0.003
radtlw3			0.015
			(0.029)
			0.603
avgcumdosew3			0.423
			(0.333)
			0.204
Constant	25520.212***	24478.002***	25456.509***
	(4704.306)	(4685.107)	(4986.699)
	0.000	0.000	0.000
adjR^2	0.355	0.366	0.344
BIC	2784.583	2775.905	2777.866
N	339	340	340

* p<0.05, ** p<0.01, *** p<0.001

We note that in wave two most of the employment categories are associated with pain. The only one that is not is the unemployed category (emplw26). The full time(emplw22), the part time(emplw23), the retired (emplw25), and the unemployed(emplw26) also during wave two are associated with pain. This may be due to the collapse of the economy during the early 1990s in the Ukraine. In the third wave, we can see that the proportion of pollution due to Chornobyl is a significant predictor of pain on the part of the males. We now have to compare these results to those for the women.

When we examine the results for women, the full models contain many non-significant terms that are too inefficient to display here. Moreover, we do not obtain significant dose-female pain models, unless we use path dependent backward stepwise elimination. This calls into question the results. Even when we perform a simultaneous trimming at a level of 0.10, no significant dose pain relationship emerges for women. On this basis we can ignore potential moderators, but mediators we find could be important.

4.1 Potential moderators

For males in wave one, age, having a technical degree and self-perceived Chornobyl health threat to oneself may be significant moderators. In wave 2 for males, age and self-injury due to Chornobyl are potential moderators. In wave 3 for males, average cumulative dose as a main effect is not a significant main effect. For females we can ignore these owing to a lack of a significant dose pain relationship on the part of the main effects.

4.2 Potential mediators

In the dose-pain relationship for males, we found that there were several variables that might be used for mediators in wave one. They were age, having a technical degree, and perceived Chornobyl health threat to oneself. In wave two, age and injury to oneself were possible mediators, and in wave three, the males exhibited the potential for being potential mediators. These were age, self-perceived Chornobyl health threat, number of times respondent was ill in wave three, perceived Chornobyl related health threat to the family. For all waves, age was a mediator between accumulated dose and pain. Chornobyl related health threat was a possible mediator in waves one and two. So the one indirect effect in all waves is probably age for the men.

For females the potential mediators were very similar. In wave one, age and education were possible mediators. In wave one, age continued to be a possible mediator with a positive effect. In wave three, age, illness count, self-reported physical health status, perceived Chornobyl health threat to oneself and one's family are possible mediators between accumulated dose and female pain. Self-reported physical health has a positive indirect effect. So do the self-perceived health threats to oneself and one's family in wave three.

5 The dose-sleep relationship in three waves

The Nottingham sleep subscale is coded 0 to 101. The male mean is 17.29 and the male standard deviation is 24.83, whereas the female mean is 26.24 and the female standard deviation is 26.244. More than 33% of both male and females scored 0, whereas 67% of the males scored 12.57 and 67% of the females scored 28.67%.

The only significant male dose-sleep relationship emerges in the first wave. The wave 2 and wave 3 relationships pale into lack of statistical significance. Among the variables statistically significant in this model contributing to better sleep are age, a full spectrum of educational attainment, concern for lifetime exposure to radiation, the wave one count of illnesses and the BSIs positive symptom inventory as well as trust in government. Because people will be interested in empirical all output, the three waves are shown here, although no dose-sleep relationship emerges in the last two waves.

Table 3: Trimmed Regression Models of reconstructed dose on male sleep

	wave1	wave2	wave3
age	0.350*	0.088	-0.042
	(0.142)	(0.163)	(0.138)
	0.014	0.589	0.761
educ2	23.247**	23.969**	22.500*
(HS grad)	(7.637)	(8.641)	(8.919)
	0.003	0.006	0.012
educ3	17.843***	19.213***	19.636**
(tech degree)	(4.533)	(5.662)	(6.138)
	0.000	0.001	0.002
educ4	22.697**	19.289*	19.594*
(some college	(6.910)	(7.748)	(8.271)
	0.001	0.013	0.018
educ5	20.230***	23.066***	20.880**
(college grad)	(5.314)	(6.442)	(6.936)
	0.000	0.000	0.003
educ6	18.589***	18.798***	19.382**
(masters degree)	(3.749)	(5.002)	(6.066)
	0.000	0.000	0.002
educ7	20.017	27.384	26.084
(Ph.D.,Sci D.)	(10.989)	(14.056)	(13.935)
	0.069	0.052	0.062
occ1w1	-13.277*		
(prof.,admin)	(6.368)		
	0.038		
occ2w1	-17.421**		
(admin support	(6.266)		
tech sales)	0.006		
occ3w1	-17.022*		
(prot. services)	(7.380)		
	0.022		

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occ4w1(precision	-12.498		
prod.craft)	(7.150)		
	0.081		
occ5w1	-13.013		
(factory labor)	(9.216)		
	0.159		
occ6w1	-21.110**		
(agric. forestry)	(6.767)		
	0.002		
occ7w1	-9.337		
(homemaking	(12.633)		
caregiving)	0.460		
occ8w1	-6.924		
(student)	(6.363)		
	0.277		
radtlw1	0.062*		
	(0.031)		
	0.047		
avgcumdosew1	1.045**		
	(0.365)		
	0.004		
suprtw2	0.074**		
(partner suppt)	(0.025)		
	0.004		
illw1	5.348		
(count of ills	(3.549)		
in wave one)	0.133		
BSIposymp	0.377*	0.550***	0.578***
(positive	(0.146)	(0.072)	(0.064)
symptoms)	0.010	0.000	0.000
BSIsoma	0.504		
(somaticism)	(0.404)		
	0.213		
BSIanx	0.959		
(anxiety)	(0.937)		
	0.307		
PTSDw1	0.062		
(PTSD self-rpt)	(0.036)		
	0.089		
sufamw1	-0.039		
(family support)	(0.041)		
	0.347		
emplw22		-47.636***	-1.245
		(4.926)	(4.239)
		0.000	0.769
emplw23		-46.292***	-0.106
		(5.498)	(5.023)
		0.000	0.983
o.emplw24		0.000	45.530***
(var omitted by		(.)	(4.610)
stat package)		.	0.000

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emplw25	-107.838***	
	(8.817)	
	0.000	
emplw26	-42.525***	8.369
	(6.868)	(7.736)
	0.000	0.280
occ1w2	5.105	
	(4.667)	
	0.275	
occ2w2	5.113	
	(4.392)	
	0.245	
occ3w2	0.972	
	(5.320)	
	0.855	
occ4w2	9.856	
	(5.175)	
	0.058	
occ5w2	6.789	
	(5.954)	
	0.255	
o.occ6w2	0.000	
	(.)	
	.	
occ7w2	63.848***	
	(7.202)	
	0.000	
occ8w2	2.127	
	(5.256)	
	0.686	
avgcumdosew2	-10.392	
	(11.117)	
	0.351	
sufamw2	0.013	
	(0.040)	
	0.743	
trgovw2 (trust in govt)	0.042	
	(0.044)	
	0.335	
ageXd2 (age by wave 2 dose)	-0.025	
(interaction)	(0.155)	
	0.873	
BSIposympXd2 (pos symptom by dose)	0.053**	
	(0.018)	
	0.004	
sufamw2Xd2	0.073*	
(family supprt by dose in wave 2)	(0.037)	
	0.049	
trgovw2Xd2	0.027*	
(trust in govt by dose in wave 2)	(0.013)	
	0.036	

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o.emplw25			0.000
			(.)
			.
avgcumdosew3			0.629
			(0.510)
			0.218
sufamw3			0.100**
			(0.034)
			0.003
trgovw3			0.104**
			(0.038)
			0.007
Constant	-59.271***	-8.018	-54.394***
	(10.865)	(16.370)	(10.986)
	0.000	0.625	0.000
adjR^2	0.393	0.398	0.395
BIC	3090.75	2781.226	2729.006
N	339	306	305

* p<0.05, ** p<0.01, *** p<0.001

The female dose-sleep may fade over time. Although it is statistically significant in the first two waves, it is quasi-significant in the last wave (Table 4 below). The amount of endogenous variance explained by these models also declines over time, as we can tell from the decline in the adjusted R^2, at the bottom of the table, which is another indication of the greater dispersion of the variance of the endogenous variable over time. Notwithstanding, the Bayesian information criterion of the last model is the smallest of the three for the nature of this female dose-sleep impact.

Table 4: Trimmed Regression Models of reconstructed dose on female sleep

	wave1	wave2	wave3
age	0.858***	0.891***	0.762***
	(0.166)	(0.135)	(0.132)
	0.000	0.000	0.000
avgcumdosew1	6.398*		
	(2.577)		
	0.013		
inc1w1	-4.983		
(insufficient	(4.876)		
income)	0.308		
inc2w1	-9.770*		
(inc sufficient	(3.959)		
for basics)	0.014		
inc3w1	-4.092		
(income is	(4.778)		
sufficient +)	0.392		
inc4w1	-9.313		
(income good	(6.127)		
for luxuries)	0.129		

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marrw11	6.723		
(single)	(6.517)		
	0.303		
marrw12	33.903		
(cohabiting)	(21.394)		
	0.114		
marrw13	2.362		
(married)	(7.542)		
	0.754		
marrw14	57.139***		
(separated)	(13.759)		
	0.000		
marrw15	2.249		
(divorced)	(15.631)		
	0.886		
marrw16	13.856		
(widowed)	(19.028)		
	0.467		
bffsl4	0.339***		
(basis func)	(0.079)		
	0.000		
bffsl10	0.004*	0.005**	0.005***
(basis fnc)	(0.002)	(0.002)	(0.001)
	0.019	0.006	0.000
bffsl11	-0.003*		
(basis fnc)	(0.001)		
	0.014		
BSIhos	1.514*	2.888***	2.981***
(hostility)	(0.678)	(0.536)	(0.500)
	0.026	0.000	0.000
avgcumdosew2		2.154*	
		(0.892)	
		0.016	
radhlw2		0.121*	
		(0.048)	
		0.012	
radchw2		-0.129**	
		(0.043)	
		0.003	
educ2		14.104*	
		(6.455)	
		0.030	
educ3		15.525**	
		(5.361)	
		0.004	
educ4		11.949	
		(8.465)	
		0.159	
educ5		6.171	
		(6.372)	
		0.333	
educ6		8.879	
		(5.240)	
		0.091	
educ7		-17.624	
		(14.139)	
		0.213	

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occ1w2	9.026	
	(7.231)	
	0.213	
occ2w2	1.533	
	(7.756)	
	0.843	
occ3w2	14.654	
	(7.614)	
	0.055	
occ4w2	6.126	
	(9.117)	
	0.502	
occ5w2	3.567	
	(11.333)	
	0.753	
occ6w2	19.595	
	(10.310)	
	0.058	
occ7w2	11.741	
	(7.672)	
	0.127	
occ8w2	18.107*	
	(8.189)	
	0.028	
inc1w2	-11.364	
	(7.459)	
	0.128	
inc2w2	-13.444	
	(7.179)	
	0.062	
inc3w2	-15.910*	
	(7.475)	
	0.034	
inc4w2	-20.648	
	(12.804)	
	0.108	
avgcumdosew3		1.515
		(0.799)
		0.059
marrw31		-14.102*
		(6.453)
		0.030
marrw32		5.354
		(10.258)
		0.602
marrw33		-3.797
		(4.140)
		0.360
marrw35		3.629
		(6.307)
		0.565

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radhlw3			0.156***
			(0.046)
			0.001
radchw3			-0.099*
			(0.044)
			0.024
Constant	-38.923***	-50.553***	-37.806***
	(8.959)	(10.283)	(9.196)
	0.000	0.000	0.000
adjR^2	0.337	0.294	0.286
BIC	3454.624	3510.085	3452.337
N	363	363	363

* p<0.05, ** p<0.01, *** p<0.001

5.1 Moderators of the dose-sleep impact

There are three possible moderators of the male dose-sleep relationship in wave two. The variables interacting with dose at wave one for males are family support, trust in government, and the BSI positive symptom subscale. They may render a non-significant main effect in the beginning noteworthy by virtue of the significance of the interactions.

As for the women in wave one, we note that a basis function comprising an interaction of death and positive symptoms on the BSI may serve as moderators. In wave two, there appears to be a significant statistical interaction between the proportion of pollution due to Chornobyl and the average cumulative dose of ^{137}CS (t = 2.07, p=0.039) reinforcing interference with sleep. In wave three, a basis function interacting with reconstructed revealed a complex five-way interaction that appeared to be statistically significantly interfering with sleep. The interaction entailed one or more death(s), air pollution in the previous wave, a lack of doctors visits, indication of positive symptoms (BSI) and some hostility (BSI). The effect was to enhance interference with sleep.

5.2 Potential sleep mediators

We discovered a number of variables that would intervene in the dose sleep relationship to influence sleep. For males, the potential mediators of the dose sleep relationship are several. In wave one, the self-perceived Chornobyl related health threat is a mediator. In wave two, age and injury to oneself because of Chornobyl are possible mediators. In wave three, injury to oneself continues to be a mediator, as does age, and the self-reported wave three illness count.

For women, there are several intervening variables that influence their sleep in wave one. Among them are anxiety from the basic symptom inventory (BSIanx), depression (BSIdep), PTSD in wave one, age, fear of going outdoors, fear of eating contaminated food, and the fact that they were injured as a result of Chornobyl, as well as the Chornobyl related health threat to the family.

In wave two, we observe that age, depression (BSI) continues to be an intervening variable, anxiety, concern about the percent of pollution due to Chornobyl, and the count of wave 2 illnesses, the perception of the Chornobyl related health threat to oneself and to their family.

In wave three, we can see that some of this is fading. Age seems to interfere with sleep as usual. Fear of eating contaminated food continues to interfere with sleep, as does depression (BSI), anxiety (BSI), the self reported status of physical health, the self-reported count of illnesses in wave three, perception of the Chornobyl related health threat to oneself and the family.

6 The Dose-Energy level Relationship in three waves

If does can affect pain and sleep, it would be surprising if did not have an effect on energy level as well. We examine nature of the dose-energy level relationship for direct, indirect, and interacting effects. Our models have the statistical power to detect small to medium effect sizes with as much as 40 parameters in the male model. Nonetheless, the male models reveal no significant dose - energy level response, even after trimming out the statistically nonsignificant parameters to endow the model with greater power, as shown in Table Five below.

Table5: Trimmed Regression Models of reconstructed dose on male energy level

	wave1	wave2	wave3
age	0.618***	0.244	0.082
	(0.179)	(0.151)	(0.141)
	0.001	0.106	0.559
educ2	28.609*	23.814	21.605
	(13.594)	(14.426)	(12.683)
	0.036	0.100	0.089
educ3	24.514*	20.903	20.896
	(12.148)	(13.889)	(11.800)
	0.044	0.133	0.077
educ4	16.351	17.502	18.785
	(12.804)	(14.435)	(12.487)
	0.202	0.226	0.133
educ5	28.903*	28.353*	26.735*
	(12.713)	(14.324)	(12.072)
	0.024	0.049	0.027
educ6	27.306*	22.599	23.612*
	(12.239)	(14.009)	(11.841)
	0.026	0.108	0.047
educ7	30.912	24.802	25.076
	(16.018)	(17.204)	(15.595)
	0.054	0.150	0.109

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marrw11	8.252		
	(6.390)		
	0.197		
marrw12	-21.773*		
	(9.477)		
	0.022		
marrw13	-2.683		
	(7.703)		
	0.728		
o.marrw14	0.000		
	(.)		
	.		
marrw15	23.106		
	(17.106)		
	0.178		
dvcew1	-35.614*		
(divorces)	(15.505)		
	0.022		
sepaw1	29.313		
(separations)	(15.124)		
	0.053		
shhlw1	-0.124*		
(hlth stresses	(0.061)		
and hassles)	0.042		
shhousw1	0.131*		
(housing hassles)	(0.059)		
	0.028		
phlthw1	-0.233*		
(physical hlth	(0.105)		
self-rpt)	0.026		
suprtw1	0.091		
	(0.055)		
	0.096		
fdferw1	0.072		
(fear of	(0.050)		
contamined food)	0.150		
healthef	0.605***	0.517***	0.449***
(health effects)	(0.144)	(0.101)	(0.130)
	0.000	0.000	0.001
carcin	-0.677***	-0.596***	-0.528***
(cancer rad risk)	(0.127)	(0.086)	(0.113)
	0.000	0.000	0.000
dafter	0.029**		
(Notification	(0.010)		
delay)	0.003		
near	-0.159***	-0.135**	-0.133**
	(0.044)	(0.043)	(0.043)
	0.000	0.002	0.002
chsize	-0.141**	-0.140**	-0.146**
(size of	(0.050)	(0.051)	(0.052)
disaster)	0.005	0.007	0.005
bfmEL2	-1.162*	-1.659**	-1.526**
	(0.512)	(0.527)	(0.538)
	0.024	0.002	0.005
bfmEL4	-0.453***	-0.383**	-0.383**
	(0.118)	(0.116)	(0.126)
	0.000	0.001	0.003

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avgcumdosew1	0.948		
	(1.058)		
	0.371		
marrw21		-6.680	
		(7.406)	
		0.368	
marrw22		-9.226	
		(9.357)	
		0.325	
marrw23		-13.393	
		(6.898)	
		0.053	
marrw25		-15.851	
		(10.922)	
		0.148	
radchw2		0.117*	
		(0.046)	
		0.011	
havmil		0.028	
		(0.023)	
		0.231	
bfmEL16		0.026	0.014*
		(0.016)	(0.007)
		0.094	0.037
suprtw2		0.067	
		(0.035)	
		0.056	
icdxcnt (medically diagnosed disease count)		3.038**	3.022**
		(0.987)	(0.986)
		0.002	0.002
avgcumdosew2		0.992	
		(1.063)	
		0.352	
emplw32			5.836
			(4.074)
			0.153
emplw33			4.134
			(4.757)
			0.385
emplw34			-5.318
			(4.594)
			0.248
radchw3			0.107*
			(0.048)
			0.025
avgcumdosew3			1.001
			(0.939)
			0.287
Constant	35384.229***	44177.838***	41521.571***
	(9604.502)	(9790.901)	(9861.935)
	0.000	0.000	0.000
adjR^2	0.350	0.361	0.350
BIC	3243.235	3240.196	3231.853
N	338	340	340

* p<0.05, ** p<0.01, *** p<0.001

Not only was there no apparent statistically significant main effect dose-energy level for men in wave three, there was no apparent statistically significant dose-energy level for women either (Table six). Other factors did affect the energy level as are indicated by the starred parameters below.

Table 6: Trimmed female energy level main effects regression models

	wave1	wave2	wave3
age	0.360*	-0.036	0.194
	(0.181)	(0.137)	(0.193)
	0.047	0.792	0.314
occ1w1	7.089		
	(5.484)		
	0.197		
occ2w1	14.470*		
	(6.327)		
	0.023		
occ3w1	10.897		
	(6.693)		
	0.104		
occ4w1	-4.146		
	(9.527)		
	0.664		
occ5w1	14.315		
	(7.756)		
	0.066		
occ6w1	7.316		
	(8.446)		
	0.387		
occ7w1	10.086		
	(7.097)		
	0.156		
occ8w1	18.404***		
	(5.530)		
	0.001		
aborw1	-3.437**		
	(1.197)		
	0.004		
sufamw1	0.140*		
	(0.056)		
	0.013		
mhlthw1	0.145*		
(mental hlth)	(0.068)		
	0.033		
polprw1	-0.070		
(effects of pol	(0.040)		
problems)	0.083		
BSIdep	0.870		
	(0.451)		
	0.055		
PTSDw1	0.129**		
	(0.045)		
	0.005		
BSIsoma	-2.981*		
	(1.439)		
	0.039		

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havmil	-0.017***	-0.014***	
	(0.004)	(0.003)	
	0.000	0.000	
bffel3	-5.830***	-2.713***	
	(1.594)	(0.376)	
	0.000	0.000	
bffel4	-0.532***	-0.527***	
	(0.086)	(0.088)	
	0.000	0.000	
chsize	0.116*	0.110*	0.161**
	(0.048)	(0.047)	(0.055)
	0.017	0.018	0.004
avgcumdosew1	-2.841		
	(2.488)		
	0.254		
polprw2		-0.102**	
		(0.034)	
		0.003	
HP2sxlife		12.525**	23.539***
		(4.089)	(4.573)
		0.002	0.000
avgcumdosew2		-0.426	
		(0.687)	
		0.535	
marrw31			-13.884
			(7.655)
			0.071
marrw32			-29.242***
			(8.260)
			0.000
marrw33			-7.126
			(6.227)
			0.253
marrw34			-5.494
			(10.101)
			0.587
marrw35			2.952
			(8.137)
			0.717
emplw32			-1.201
			(6.383)
			0.851
emplw33			34.167***
			(3.507)
			0.000
emplw34			8.436
			(4.916)
			0.087

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polprw3			-0.088*
			(0.042)
			0.036
fdferw3			0.200**
			(0.075)
			0.008
avgcumdosew3			-0.166
			(0.721)
			0.818
Constant	86.565*	68.670***	11.363
	(37.258)	(9.194)	(12.615)
	0.021	0.000	0.368
adjR^2	0.518	0.484	0.246
BIC	3432.834	3403.699	3564.524
N	362	363	363

* p<0.05, ** p<0.01, *** p<0.001

Among women, we observe that age can affect energy level, as can having a sales, as can having a technical, sales or administrative support (occ2w1) position or being a student at the time (occ8w1). Energy seems to improve with age but having an abortion in wave one (aborw1) can result in a decline in energy level for women. Family support (sufamw1) can also have a positive impact on energy level. However a belief that political problems can affect one (polprw1 and polprw3) can decrease the persona energy level. Self-reported post-traumatic stress syndrome (PTSDw1) significantly impacts energy level whereas somatization (BSIsoma) of illnesses is associated with a decline in energy level.

Residential distance from Chornobyl measured by the Haversine formula in miles (havmil) is significantly inversely related to energy level in waves two and three for women. Two basis functions (bffel3 and bffel4) are shown to have had a statistically significant effect as well. bffel3 is a recentering of the BSI somatic scale (bbel3= max(0, 23-BSIsoma) whereas bffel4 = max(0, phlthw3-40) is a recentering of self-reported wave three physical health, which is indicative change in physical health as compared to wave three.

Appreciation of the enormity of the Chornobyl disaster (chsize) persists in significance from wave two to wave three as a factor affecting energy level. Appreciation of the consequences of political problems can depress female energy levels in wave two. However, the sex life (HP2sxlife) can also positively affect the energy level as shown in waves two and three.

In wave three, cohabiting can result in a statistically significant decline in female energy level (marrw32). It is interesting tot note that fear of eating contaminated food persists into wave three (fderw3).

6.1 Moderation of the Dose Energy level relationship

When the main effects are not significant in a model, people often do not look to see if there are significant interactions that could potentiate the main effects into significance. In wave one, there were five interactions between variables and dose that had an effect on male energy level. Those variables were age, partner support, fear of eating contaminated food, belief that Chornobyl was the largest nuclear disaster, and count of medically diagnosed illnesses. Fear of eating contaminated food and age had a negative effect on the energy level, whereas the others had an overall positive effect.

By wave two, there were no statistically significant moderators.By wave three, the only possible moderator was the interaction of dose and the belief in the proportion of pollution that was due to Chornobyl. Those who believed that the proportion of pollution due to Chornobyl was low exhibited more energy level than other men.

The females exhibit no reliable moderating effects in waves one and two, or three.

6.2 Mediation of the Dose energy level relationship

If there is no statistically significant direct effect of average cumulative dose of ^{137}CS on the energy level of the respondent, is it possible that the dose - energy level relationship can be mediated by other variables? Our analysis shows that there are a variety of variables that might intervene in this relationship. Sleep (or lack thereof), when measured by the Nottingham subscale, can be seen to interfere with the dose-energy level relationship. Other mediating variables are anxiety (BSI), depression (self-reported), and Chornobyl related health threats can do so. For example, in wave one, male fear of going outside was a mediating or intervening variable.

During wave two, sleep as a mediator began to lose its statistical significance. Its significance faded into a status of being almost statistically significant at the .05 level ($p = 0.054$). However, age, as almost always, turns out to be a significant mediator ($p < 0.026$) in the dose-energy relationship. Sex life ($p < 0.031$) also appears to be able to statistically significantly interfere with sleep, according to a preliminary path analysis.

In wave three, age for men maintains its status as a mediating variable and sleep resumes its status as a mediator ($p = 0.026$). Sex life also maintains its status as a variable than can interfere with sleep. However, now the Chornobyl related health threat to the family becomes a significant intervening variable between dose and energy level ($p = .025$). The self-reported count of illnesses ($p = 0.028$) during wave three can also interfere with the dose sleep effect.

As for the females, there are seven variables that can be deemed to be mediators in wave one. Age, medically diagnosed illness count (icdxcnt), depression (BSI), anxiety measured both by the BSI and self-report, self-reported PTSDw1, sex life (Nottingham), and self-reported depression (depagw1) are shown to be possible mediators at wave one.

These findings summarize our findings regarding the main dose-psychological response sequelae of the Chornobyl disaster, suggested in part one of hypothesis one of our proposal.In the next section, we will address part two of hypothesis one, where we address the impacts on activities of daily life.

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File Attachment #102

Hypothesis One, Part One:

Findings Relating to Associations between Reconstructed External Dose

of ^{137}Caesium and Psychological Sequelae of Chornobyl (Hypothesis 1)

DRU: Modeling Nuclear Disaster Risk: The Effects of Perceived Risk and Radiation Exposure on Post-Chornobyl Psychosocial and Health Behavior Outcomes in Ukrainian Residents
NSF Grant 082 6893

30 September 2012

Contents

7 Introduction

In this section of the report, we discuss 24 hypotheses formulated within the grant proposal and the methods by which we test those hypotheses. In this section we address hypothesis one, which states that radiation does directly and significantly explains and hence predicts self-reported health as measured by the Nottingham health scale. Our sample, consisting of 340 male respondents and 363 female respondents was obtained by a process of random digit phone number selection. Thus, the sample was designed to be a probability selection of the population. In this section, we focus on three primary domains of the first part of the Nottingham health profile–namely, those domains which pertain to pain, sleep, and energy level. In so doing, we examine the dose-response relationship to them. The average cumulative dose of Caesium 137 is measured in milliGrays. Caesium 137, which is sometimes abbreviated as ^{137}CS or CS^{137} has a half-life of approximately 30 years. This isotope is used as the indicator because its deposition can be considered a general indicator of the kind of radiation deposited under circumstances that are worthy of note. It is an isotope that could conceivably still be a matter of concern, unlike Iodine 131, which has a half-life of about 8 days. This dose is the amount of the radiation that the body has been exposed to by where and how the respondent has reported his living, working, drinking, eating and other pastimes during the study period.

The second part of the Nottingham health profile pertains to general activities of life– more specifically, to paid employment, home care, problems with the family at home, problems with the sex life, problems with the social life, impacts on interests and hobbies, and impacts on vacation plans.

Because one of the objectives is to discover the key relationships whose configurations forms the etiological pathways through which dose effects the psychological sequelae of Chornobyl, we divide these effects into direct, indirect, and total effects. For this reason, when we call an effect a direct effect, we refer to it not as a direct as opposed to an inverse relationship, but rather as direct as opposed to an indirect effect. A direct effect can be positive or negative in its relationship. It need not be a positive one. However, it must be statistically significant to be empirically based.

Therefore, we operationalize the Nottingham health profile by encoding the terms and weighting them as they are prescribed by the authors of that system of subscales. For reasons to be explained psychologically, we focus on the subscales deemed to be most important to our objectives in determining the effects of consequence. The Nottingham pain subscale extends from 0 to 82.75, regardless of gender. The male mean on this scale for our sample is 10.18 and the female mean is 18.01. The standard deviation for the males is 16.45 and for the females it is 22.33. Zero is a valid score on this scale and 207(60.88%) of the 340 males report a score of 0, whereas 158 (43.53%) of the 363 females report a score of zero. For the males, 67.05% report a score of 9.99 or less. For the females, 67.77% report a pain score of 23.37 or less. Both male and female distributions have a positive skew. The male skewness is 1.75 and the female skewness is 1.15. In short, 51.92% of all respondents report a score of 0.

In general, this section pertaining to part one of the Nottingham is organized as follows. For each of the pain, sleep, and energy level subscales, we will examine the relationship for men and women in each of three waves. We will examine the direct effects from a a linear regression in part one, potential moderators from a first-order interaction analysis, and potential mediators from a preliminary structural equation model. We will explain any moderation that could affect the direct effect

8 DIRECT EFFECTS ON MENTAL HEALTH AND PHYSICAL HEALTH

8.1 H1: Radiation dose directly significantly predicts self-reported health as measured by Nottingham Health Scale

The Nottingham health profile consists of two parts. We examine the subscales of the Nottingham that related to physical and psychological health. The first part consists of a set of subscales, weighted and a second part relates to impact of health problems on the lives of the respondent. We address the part 1 subscales relating to energy level, pain, and sleep. Part 2 of the Nottingham pertains to areas impact of the health problems suffered by the respondent–consisting of paid employment; home cleaning, cooking, and repairs; social life ; causing problems with family members at home; sex life; interests and hobbies; and vacations.

We can examine the relationship to be tested in several ways. First, we can examine the zero-order relationship, without the use of other covariates. This might provide us with a sense of the total relationship and as a point of departure.

These phenomena, represented by these subscales, do not exist *in vacuo*. They arise in real situations in which a number of potentially confounding influences also exist. We have to partial out or control in order for alternative effects effects to properly arrive at an understanding of the nature of the targeted relationship to be tested. We will endeavor to include the principal confounders in a regression analysis in order to properly the relationship targeted by our hypothesis. We do this in several ways. We can include them as other independent covariates in the regression and partial out their competing or enhancing effects. We can test interactions to determine whether there are joint relationships over and above the individual direct relationships that reinforce or suppress the strength of the main effect, resulting in a moderated total effect. Alternatively, we can test their zero order relationships as mediating relationships to determine whether there are intervening or mediating variables which may be necessary for an indirect effect to occur. If an indirect effect is coupled with a direct effect, the combined effect may be more or less than what an individual direct effect might be.

Therefore, at this point we test alternative paths to determine whether there might be a mediator that could influence the direct effect. If a variable intervenes between our endogenous pain variable and our average cumulative reconstructed dose, two links to the indirect relationship are established. The first link proceeds from the dose to the mediating variable, and the second link proceeds from the mediating variable to the pain subscale. To properly explain this point, we have to assume that the regression coefficients describing the sign, magnitude, and significance of those relationship links are the same. That is, we assume that if one comes from an ordinary least squares regression, the second regression will also come from the same kind of a regression analysis. We cannot have one link coming from a classical ordinary least squares regression and another link coming from a logistic regression for those regression coefficients would not be the same. If they are not the same, they could not given our objectives multiply one by the other and come out with a product that would be comparable to an indirect effect generated by two OLS regressions. When a mediator or intervening variable exists through which an indirect effect is passed, the strength of the indirect effect is computed by multiplying the coefficient representing the first link with the coefficient representing the second link.

In a path analysis, we have to determine which effects are direct effects by determining which other effects might be indirect effects. The total effect is the sum of the direct, indirect, and spurious effects. By estimating the direct and indirect effects, we may add them to obtain the total effects. However, there are two types of spurious effects. They consist of those that we know about and those that we don't know about.

The spurious effects that we know about can be computed by subtracting the direct and indirect effects from the zero-order relationship, which we use as our starting point. What is left over is the spurious effect that we know about.

The spurious effect that we do not know about can be any unsuspected antecedent variable that is related to our supposedly exogenous cumulative dose and our presumed endogenous pain subscale. However, if there is an antecedent variable, unbeknownst to us, our presumed exogenous dose is no longer exogenous but predetermined or influenced by that unknown prior "cause.". Such a situation would endow our observed relationship with an uncertainty that might not be possible to estimate. It would also preclude us of being 100% certain of much of anything.

Our objective is to minimize any kind of specification error we can by including all of the potentially related variables and thus forming some sort of general unrestricted model as a starting point. For this reason, we add covariates that could provide alternative plausible explanations to the relationship we are testing to control for their effects [1, 25-26].

Among the variables we employ as confounders are the socio-demographic characteristics of the respondents, the computed geodesic distance in miles from the accident site, as well as local measures of support that the respondents

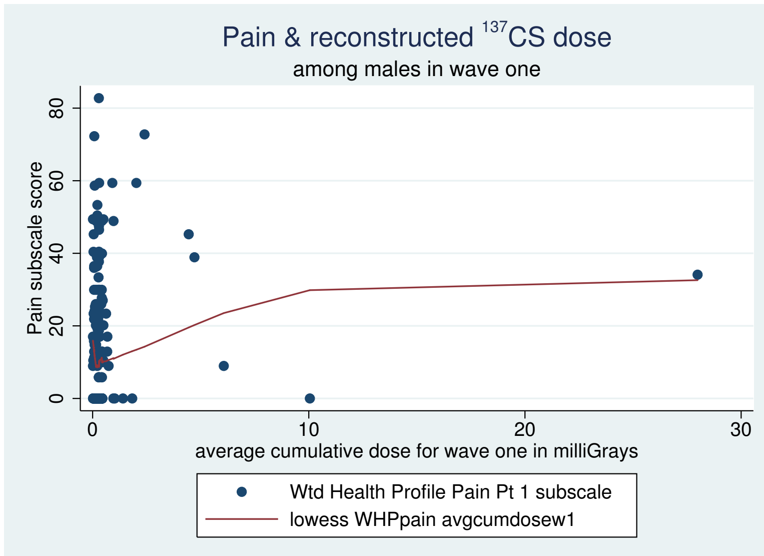

Figure 7: **Male Pain and reconstructed cumulative dose in wave 1**

might experience. As for the sociodemographic characteristics we employ martial status, the number of children for women, and income sufficiency for various levels of quality of life. We also control for perception of risk to oneself of the Chornobyl related health threat in addition to some function of the distance of the respondent at the time of the accident from Chornobyl.

8.2 The Dose-Response relationship in three waves

We will perform this analysis with separate models for males and females prior to comparison of them. Before we decide how to analyze these response patterns, we graph the endogenous variables of the Nottingham Part I scale. The purpose of the graph is to provide a visualization of the nature of the relationship before we commence our analysis. We will graph this relationship for men and women in three waves to see how it differs between men and women and to see how it evolves for each gender over time. When we examine these graphs, in Figures 1 through 6, we observe that as time passes the relationship tends to attenuate. For the males, the later graphs depict more of a decline in the slope, whereas for the females, the graphs depict more of a leveling off of the relationship. The relationship becomes a little more diffuse over time, but this is not as apparent as the attenuation. The first of these subscales we consider is male report of the Nottingham pain subscale, found in Figure 1. If we examine the pain reported by the males and females over the three waves of the study, we can observe they are not constant over time.

From Figure 1 we observe that the pattern of rise and leveling off of the

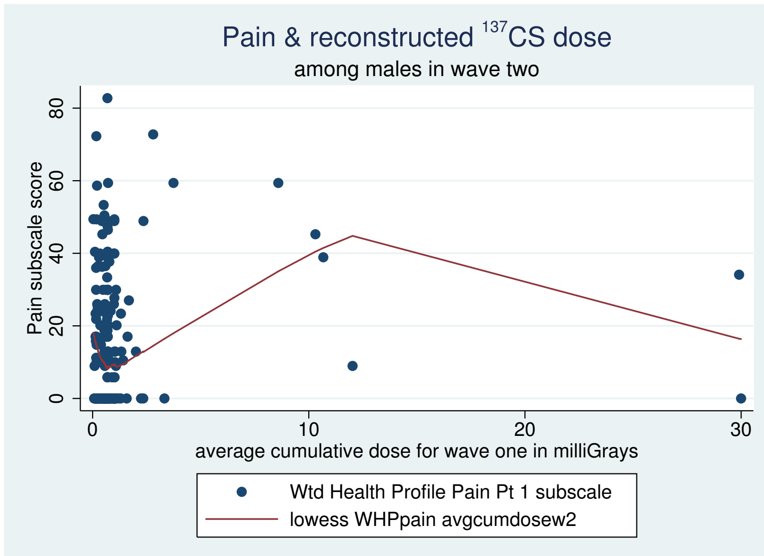

Figure 8: **Male Pain and reconstructed cumulative dose in wave 2**

relationship between the reported male pain over time. In 1986, wave one, the pattern exhibits a leveling off at the level of approximately 10 milliGrays of average cumulative dose of ^{137}CS. In wave two, this turning and the relationship appears even more sharply but at about 13.5 milliGrays. After this turning point the slope assumes the shape of a negative decline. Within wave three, slope increases until approximately 14 milliGrays, whereupon it also sharply turns into a linear decline.

From the male analysis, we observe that the relationship that we will be analyzing does not appear to have a linear form. It is a lowess graph so the line running through it is a least squares line within a given bandwidth. In order to deal with this structure, we will use regression splines to accommodate the change in direction or slope. We will generate these as part of the multivariate adaptive regression spline package called MARS [2] developed by Jerry Friedman and marketed by Salford Systems in San Diego, California. MARS automatically constructs basis functions that minimize the loss function applied to the analysis. Where they turned out to be statistically significant improvements for our analysis that enabled us to model hockey stick shaped forms of the relationship between the endogenous variable and our independent variables, we employed these regression splines to facilitate modeling delayed or threshold type associations. We define these functions as they emerge as statistically significant predictors in our analysis. More often than not, they entail a recentering of our existing variables that enable us to analyze otherwise nonlinear relationships.

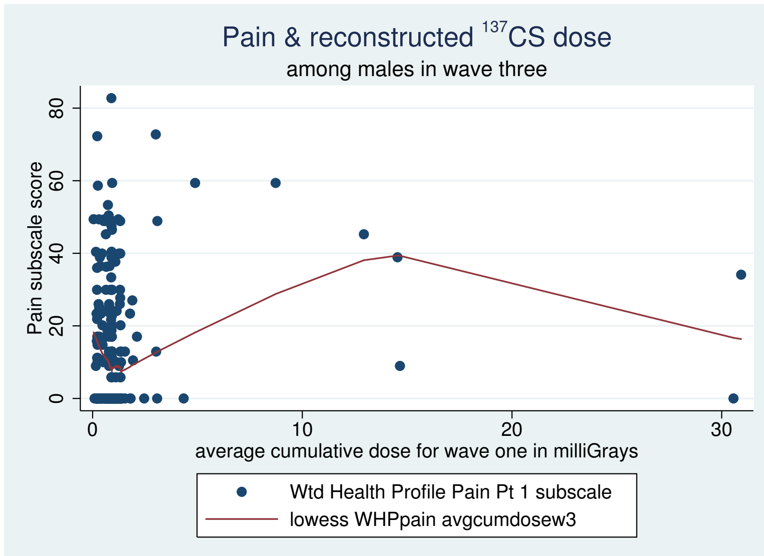

Figure 9: **Male Pain and reconstructed cumulative dose in wave 3**

Because there is no summary score for the Nottingham we have to use the subscales. We take five subscales from Part I and 7 subscales from part 2 and address salient aspects of a matrix of relationships that summarizes prominent aspects of the relationships. First, we want to know whether there exists a significant statistical relationship between reconstructed dose and the subscale of the Nottingham being considered. Second, we want to know whether this relationship is moderated or mediated by other variables. Otherwise, we cannot know for sure whether any relationship really exists. It may be that there may be a zero-order relationship but not a relationship where other covariates likely to confound the situation exist. Therefore, we test three types of relationships. Zero-order direct relationships, moderated relationships, and mediated relationships to discover under what circumstances we might find the dose-response relationship for which we are searching.

In the female analysis, we also have to examine the nature of the endogenous variables. As we do, we will notice a difference in the pain pattern. Instead of reaching a peak at which the sign of the slope undergoes a change in the downward direction, we observe that it merely declines in magnitude rather than in its directional sign.

We can get a sense of how this changes if we employ basis functions or regression splines to facilitate our analysis. We use Multivariate Adaptive Regression splines (MARS) to identify nonparametric a set of regression splines based on basis functions that turn out to be statistically significant predictors. MARS

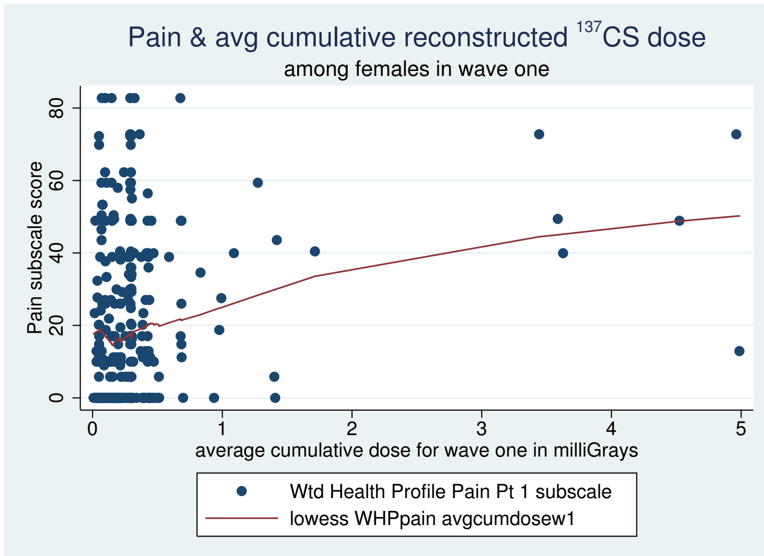

Figure 10: **Female Pain and reconstructed cumulative dose in wave 1**

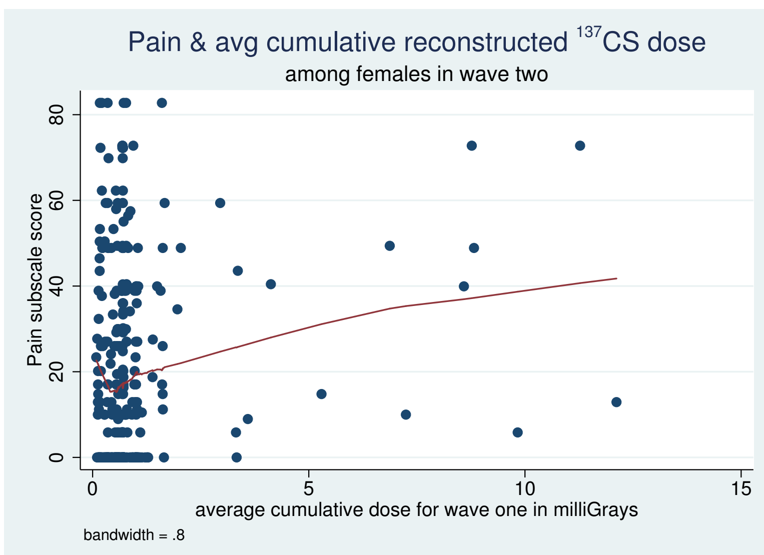

Figure 11: **Female Pain and reconstructed cumulative dose in wave 2**

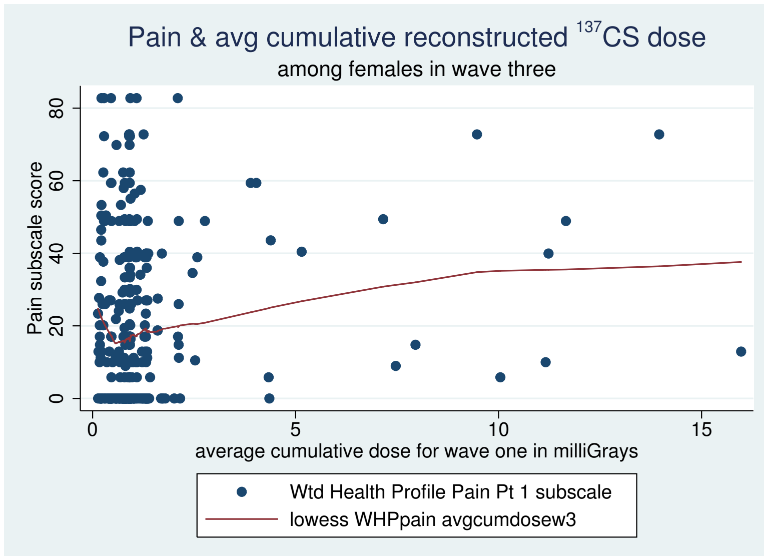

Figure 12: **Female Pain and reconstructed cumulative dose in wave 3**

9 Hypothesis 1 part 1

10 The Dose-Pain relationship

In this analysis we explore the dose-response relationship between reconstructed dose of ^{137}Caesium and pain, sleep, and energy level. To determine which are the direct effects, as opposed to indirect effects, we have to determine what effects are the indirect effects and which effects are the moderating effects.

With a view toward identifying the principle parts of our path analysis, we commence with a study of the dose psychological response relationship of pain. We divide this study into three waves. Wave one covers the time of the accident until the end of the 1986 year. Wave two extends from January 1, 1987 through December 31, 1996, and wave three runs from January 1, 1997 until the time of the interview in 2009, 2010, or 2011. However, in order to uniformitize the end-point, we ceased dose reconstruction as of January 1, 2009. We analyze men and women separately within each wave. Altogether, we have six analyses to deal with each hypothesis.

We commence with an analysis of the zero-order effects of average cumulative dose of ^{137}Caesium on pain as measured by the Nottingham health profile. This is not merely an academic exercise. It is a first part of a path analysis in order to determine the size and direction of the total effect. We commence with a zero-order test for the relationship between reconstructed cumulative dose for wave 1 and pain. For males, the measure of pain is statistically significant in a regression of pain on average cumulative dose in wave 1 only ($b = 1.112,\ se = .3785,\ t = 2.93,\ p > |t| = 0.004$). When we control for potentially confounding factors such as age, educational attainment, marital status, family size,employment status, occupational status, income sufficiency, the perception of Chornobyl related health risk to oneself, as well as the residential distance to the Chornobyl plant the relationship retains statistical significance ($b = 1.032,\ se = .332,\ t = 3.11\ p > |t|\ = 0.002$). In waves two and three, this relationship did not appear to be statistically significant.

As for females, a different story emerges. Regardless of the wave, a statistically significant relationship emerges between the reconstructed cumulative dose through the specific wave, on the one hand, and pain as defined by the Nottingham weighted health profile, on the other. Table one reveals the ordinary least squares regression coefficients and their robust standard errors in parentheses below for the average cumulative dose of ^{137}CS at the time of each wave.

Table 1: Effects of reconstructed dose on female pain from ordinary least squares regressions.

Zero-order regression coefficients of reconstructed dose on female pain

	wave1	wave2	wave3
avgcumdosew1	7.950***		
se	(2.295)		
t	3.463		
p	0.001		
avgcumdosew2		2.451*	
		(1.017)	
		2.410	
		0.016	
avgcumdosew3			1.794*
			(0.787)
			2.278
			0.023
Constant	15.344***	15.816***	15.856***
	(1.377)	(1.444)	(1.466)
	11.141	10.953	10.818
	0.000	0.000	0.000
adjR^2	0.036	0.020	0.017
bic	3281.569	3287.288	3288.427
N	363	363	363

* p<0.05, ** p<0.01, *** p<0.001

Zero-order regression relationships are virtually *in vacuo*. We endeavor to make the model more realistic by attempting to control for potentially confounding effects of alternative plausible explanations by including socio-demographic and and sometimes psychological factors. We also introduce such covariates to minimize model specification error. When we add these realistic explanations, the results can change.

We enter a full model, which controlled for age, education, occupational status,and income sufficiency, and none of these turned out to be significant predictors. Consequently, we trim them from the model. When we re-estimate the trimmed model, we obtain a result similar to that of the zero-order relationships. In that only the first wave dose-pain relationship remains statistically significant, we obtain the same result, shown in Table two below.

Other than the constant in the regression model, the only statistically significant variable in all three equations and that is a basis interaction generated by MARS that includes a basis function, called $bfmPain15 = max(0, 21918 - illw3) * bfmPain2$ with $bfmPain2 = max(0, 21935 - BSIsoma)$ The $Illw3$ variable is a count of the number of illnesses the respondent reported in wave three and the $BSIsoma$ variable is a Basic symptom inventory somaticism subscale score [2]. Apparently, voluntary employment is associated with pain as well in waves one and two (emplw14 and emplw24). By wave three, the percent of the pollution due to Chornobyl (radchw3) is also associated with male pain.

There are a few variables that are statistically significant in two of the three models. One of these is another regression spline generated by MARS which is called $bfmPain2 = max(0, 21935 - BSIsoma)$, and this is a recentering of the somatic subscale of the Basic Symptom Inventory [3, 115-127].

Table 2: Main effects regression models of reconstructed dose on male pain

	wave1 1986	wave2 1987-1996	wave3 1997-interview
age (in years)	0.073 (0.095) 0.442	0.020 (0.076) 0.796	0.017 (0.089) 0.850
emplw12 (full time in 1986)	3.333 (4.353) 0.444		
emplw13 (part time in wave 1(1986)	2.631 (4.056) 0.517		
emplw14 (voluntary)	64.343*** (6.168) 0.000		
emplw15 (retired)	9.097 (5.361) 0.091		
emplw16 (unemployed)	4.286 (4.225) 0.311		
radhlw1 (hlth threat to oneself in 1986)	-0.031 (0.038) 0.408		
radfmw1 (hlth threat to family in 1986)	0.024 (0.036) 0.512		
radtlw1 (lifetime exposure)	0.054 (0.031) 0.086		
radchw1 (prop pollution due to Chornobyl)	0.030 (0.031) 0.333		
havmil (residentl distance frm Ch)	0.002 (0.007) 0.725	0.002 (0.007) 0.776	0.001 (0.006) 0.848
bfmPain2 (basis func)	3.833** (1.230) 0.002	3.033** (1.157) 0.009	2.005 (1.204) 0.097
bfmPain15 (basis func)	-0.000*** (0.000) 0.000	-0.000*** (0.000) 0.000	-0.000** (0.000) 0.006
avgcumdosew1 (cumlative dose in wave one)	0.798** (0.279) 0.004		

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emplw22		6.400*	
		(2.535)	
		0.012	
emplw23		6.961*	
		(2.891)	
		0.017	
emplw24		69.088***	
		(3.667)	
		0.000	
emplw25		10.609*	
		(5.078)	
		0.037	
emplw26		3.246	
		(3.389)	
		0.339	
radhlw2		0.024	
		(0.026)	
		0.363	
radchw2		0.052	
		(0.032)	
		0.104	
radtlw2		0.035	
		(0.031)	
		0.250	
avgcumdosew2		0.438	
		(0.333)	
		0.190	
emplw32			-0.859
			(2.274)
			0.706
emplw33			3.900
			(2.955)
			0.188
emplw34			-0.172
			(2.800)
			0.951
radhlw3			0.028
			(0.032)
			0.382
radchw3			0.092**
			(0.031)
			0.003
radtlw3			0.015
			(0.029)
			0.603
avgcumdosew3			0.423
			(0.333)
			0.204
Constant	25520.212***	24478.002***	25456.509***
	(4704.306)	(4685.107)	(4986.699)
	0.000	0.000	0.000
adjR^2	0.355	0.366	0.344
BIC	2784.583	2775.905	2777.866
N	339	340	340

* p<0.05, ** p<0.01, *** p<0.001

We note that in wave two most of the employment categories are associated with pain. The only one that is not is the unemployed category (emplw26). The full time(emplw22), the part time(emplw23), the retired (emplw25), and the unemployed(emplw26) also during wave two are associated with pain. This may be due to the collapse of the economy during the early 1990s in the Ukraine. In the third wave, we can see that the proportion of pollution due to Chornobyl is a significant predictor of pain on the part of the males. We now have to compare these results to those for the women.

When we examine the results for women, the full models contain many non-significant terms that are too inefficient to display here. Moreover, we do not obtain significant dose-female pain models, unless we use path dependent backward stepwise elimination. This calls into question the results. Even when we perform a simultaneous trimming at a level of 0.10, no significant dose pain relationship emerges for women. On this basis we can ignore potential moderators, but mediators we find could be important.

10.1 Potential moderators

For males in wave one, age, having a technical degree and self-perceived Chornobyl health threat to oneself may be significant moderators. In wave 2 for males, age and self-injury due to Chornobyl are potential moderators. In wave 3 for males, average cumulative dose as a main effect is not a significant main effect. For females we can ignore these owing to a lack of a significant dose pain relationship on the part of the main effects.

10.2 Potential mediators

In the dose-pain relationship for males, we found that there were several variables that might be used for mediators in wave one. They were age, having a technical degree, and perceived Chornobyl health threat to oneself. In wave two, age and injury to oneself were possible mediators, and in wave three, the males exhibited the potential for being potential mediators. These were age, self-perceived Chornobyl health threat, number of times respondent was ill in wave three, perceived Chornobyl related health threat to the family. For all waves, age was a mediator between accumulated dose and pain. Chornobyl related health threat was a possible mediator in waves one and two. So the one indirect effect in all waves is probably age for the men.

For females the potential mediators were very similar. In wave one, age and education were possible mediators. In wave one, age continued to be a possible mediator with a positive effect. In wave three, age, illness count, self-reported physical health status, perceived Chornobyl health threat to oneself and one's family are possible mediators between accumulated dose and female pain. Self-reported physical health has a positive indirect effect. So do the self-perceived health threats to oneself and one's family in wave three.

11 The dose-sleep relationship in three waves

The Nottingham sleep subscale is coded 0 to 101. The male mean is 17.29 and the male standard deviation is 24.83, whereas the female mean is 26.24 and the female standard deviation is 26.244. More than 33% of both male and females scored 0, whereas 67% of the males scored 12.57 and 67% of the females scored 28.67%.

The only significant male dose-sleep relationship emerges in the first wave. The wave 2 and wave 3 relationships pale into lack of statistical significance. Among the variables statistically significant in this model contributing to better sleep are age, a full spectrum of educational attainment, concern for lifetime exposure to radiation, the wave one count of illnesses and the BSIs positive symptom inventory as well as trust in government. Because people will be interested in empirical all output, the three waves are shown here, although no dose-sleep relationship emerges in the last two waves.

Table 3: Trimmed Regression Models of reconstructed dose on male sleep

	wave1	wave2	wave3
age	0.350*	0.088	-0.042
	(0.142)	(0.163)	(0.138)
	0.014	0.589	0.761
educ2	23.247**	23.969**	22.500*
(HS grad)	(7.637)	(8.641)	(8.919)
	0.003	0.006	0.012
educ3	17.843***	19.213***	19.636**
(tech degree)	(4.533)	(5.662)	(6.138)
	0.000	0.001	0.002
educ4	22.697**	19.289*	19.594*
(some college	(6.910)	(7.748)	(8.271)
	0.001	0.013	0.018
educ5	20.230***	23.066***	20.880**
(college grad)	(5.314)	(6.442)	(6.936)
	0.000	0.000	0.003
educ6	18.589***	18.798***	19.382**
(masters degree)	(3.749)	(5.002)	(6.066)
	0.000	0.000	0.002
educ7	20.017	27.384	26.084
(Ph.D.,Sci D.)	(10.989)	(14.056)	(13.935)
	0.069	0.052	0.062
occ1w1	-13.277*		
(prof.,admin)	(6.368)		
	0.038		
occ2w1	-17.421**		
(admin support	(6.266)		
tech sales)	0.006		
occ3w1	-17.022*		
(prot. services)	(7.380)		
	0.022		

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occ4w1(precision	-12.498		
prod.craft)	(7.150)		
	0.081		
occ5w1	-13.013		
(factory labor)	(9.216)		
	0.159		
occ6w1	-21.110**		
(agric. forestry)	(6.767)		
	0.002		
occ7w1	-9.337		
(homemaking	(12.633)		
caregiving)	0.460		
occ8w1	-6.924		
(student)	(6.363)		
	0.277		
radtlw1	0.062*		
	(0.031)		
	0.047		
avgcumdosew1	1.045**		
	(0.365)		
	0.004		
suprtw2	0.074**		
(partner suppt)	(0.025)		
	0.004		
illw1	5.348		
(count of ills	(3.549)		
in wave one)	0.133		
BSIposymp	0.377*	0.550***	0.578***
(positive	(0.146)	(0.072)	(0.064)
symptoms)	0.010	0.000	0.000
BSIsoma	0.504		
(somaticism)	(0.404)		
	0.213		
BSIanx	0.959		
(anxiety)	(0.937)		
	0.307		
PTSDw1	0.062		
(PTSD self-rpt)	(0.036)		
	0.089		
sufamw1	-0.039		
(family support)	(0.041)		
	0.347		
emplw22		-47.636***	-1.245
		(4.926)	(4.239)
		0.000	0.769
emplw23		-46.292***	-0.106
		(5.498)	(5.023)
		0.000	0.983
o.emplw24		0.000	45.530***
(var omitted by		(.)	(4.610)
stat package)		.	0.000

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emplw25	-107.838***	
	(8.817)	
	0.000	
emplw26	-42.525***	8.369
	(6.868)	(7.736)
	0.000	0.280
occ1w2	5.105	
	(4.667)	
	0.275	
occ2w2	5.113	
	(4.392)	
	0.245	
occ3w2	0.972	
	(5.320)	
	0.855	
occ4w2	9.856	
	(5.175)	
	0.058	
occ5w2	6.789	
	(5.954)	
	0.255	
o.occ6w2	0.000	
	(.)	
	.	
occ7w2	63.848***	
	(7.202)	
	0.000	
occ8w2	2.127	
	(5.256)	
	0.686	
avgcumdosew2	-10.392	
	(11.117)	
	0.351	
sufamw2	0.013	
	(0.040)	
	0.743	
trgovw2 (trust in govt)	0.042	
	(0.044)	
	0.335	
ageXd2 (age by wave 2 dose)	-0.025	
(interaction)	(0.155)	
	0.873	
BSIposympXd2 (pos symptom by dose)	0.053**	
	(0.018)	
	0.004	
sufamw2Xd2	0.073*	
(family supprt by dose in wave 2)	(0.037)	
	0.049	
trgovw2Xd2	0.027*	
(trust in govt by dose in wave 2)	(0.013)	
	0.036	

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o.emplw25			0.000
			(.)
			.
avgcumdosew3			0.629
			(0.510)
			0.218
sufamw3			0.100**
			(0.034)
			0.003
trgovw3			0.104**
			(0.038)
			0.007
Constant	-59.271***	-8.018	-54.394***
	(10.865)	(16.370)	(10.986)
	0.000	0.625	0.000
adjR^2	0.393	0.398	0.395
BIC	3090.75	2781.226	2729.006
N	339	306	305

* p<0.05, ** p<0.01, *** p<0.001

The female dose-sleep may fade over time. Although it is statistically significant in the first two waves, it is quasi-significant in the last wave (Table 4 below). The amount of endogenous variance explained by these models also declines over time, as we can tell from the decline in the adjusted R^2, at the bottom of the table, which is another indication of the greater dispersion of the variance of the endogenous variable over time. Notwithstanding, the Bayesian information criterion of the last model is the smallest of the three for the nature of this female dose-sleep impact.

Table 4: Trimmed Regression Models of reconstructed dose on female sleep

	wave1	wave2	wave3
age	0.858***	0.891***	0.762***
	(0.166)	(0.135)	(0.132)
	0.000	0.000	0.000
avgcumdosew1	6.398*		
	(2.577)		
	0.013		
inc1w1	-4.983		
(insufficient	(4.876)		
income)	0.308		
inc2w1	-9.770*		
(inc sufficient	(3.959)		
for basics)	0.014		
inc3w1	-4.092		
(income is	(4.778)		
sufficient +)	0.392		
inc4w1	-9.313		
(income good	(6.127)		
for luxuries)	0.129		

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marrw11	6.723		
(single)	(6.517)		
	0.303		
marrw12	33.903		
(cohabiting)	(21.394)		
	0.114		
marrw13	2.362		
(married)	(7.542)		
	0.754		
marrw14	57.139***		
(separated)	(13.759)		
	0.000		
marrw15	2.249		
(divorced)	(15.631)		
	0.886		
marrw16	13.856		
(widowed)	(19.028)		
	0.467		
bffsl4	0.339***		
(basis func)	(0.079)		
	0.000		
bffsl10	0.004*	0.005**	0.005***
(basis fnc)	(0.002)	(0.002)	(0.001)
	0.019	0.006	0.000
bffsl11	-0.003*		
(basis fnc)	(0.001)		
	0.014		
BSIhos	1.514*	2.888***	2.981***
(hostility)	(0.678)	(0.536)	(0.500)
	0.026	0.000	0.000
avgcumdosew2		2.154*	
		(0.892)	
		0.016	
radhlw2		0.121*	
		(0.048)	
		0.012	
radchw2		-0.129**	
		(0.043)	
		0.003	
educ2		14.104*	
		(6.455)	
		0.030	
educ3		15.525**	
		(5.361)	
		0.004	
educ4		11.949	
		(8.465)	
		0.159	
educ5		6.171	
		(6.372)	
		0.333	
educ6		8.879	
		(5.240)	
		0.091	
educ7		-17.624	
		(14.139)	
		0.213	

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occ1w2	9.026	
	(7.231)	
	0.213	
occ2w2	1.533	
	(7.756)	
	0.843	
occ3w2	14.654	
	(7.614)	
	0.055	
occ4w2	6.126	
	(9.117)	
	0.502	
occ5w2	3.567	
	(11.333)	
	0.753	
occ6w2	19.595	
	(10.310)	
	0.058	
occ7w2	11.741	
	(7.672)	
	0.127	
occ8w2	18.107*	
	(8.189)	
	0.028	
inc1w2	-11.364	
	(7.459)	
	0.128	
inc2w2	-13.444	
	(7.179)	
	0.062	
inc3w2	-15.910*	
	(7.475)	
	0.034	
inc4w2	-20.648	
	(12.804)	
	0.108	
avgcumdosew3		1.515
		(0.799)
		0.059
marrw31		-14.102*
		(6.453)
		0.030
marrw32		5.354
		(10.258)
		0.602
marrw33		-3.797
		(4.140)
		0.360
marrw35		3.629
		(6.307)
		0.565

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radhlw3			0.156***
			(0.046)
			0.001
radchw3			-0.099*
			(0.044)
			0.024
Constant	-38.923***	-50.553***	-37.806***
	(8.959)	(10.283)	(9.196)
	0.000	0.000	0.000
adjR^2	0.337	0.294	0.286
BIC	3454.624	3510.085	3452.337
N	363	363	363

* p<0.05, ** p<0.01, *** p<0.001

11.1 Moderators of the dose-sleep impact

There are three possible moderators of the male dose-sleep relationship in wave two. The variables interacting with dose at wave one for males are family support, trust in government, and the BSI positive symptom subscale. They may render a non-significant main effect in the beginning noteworthy by virtue of the significance of the interactions.

As for the women in wave one, we note that a basis function comprising an interaction of death and positive symptoms on the BSI may serve as moderators. In wave two, there appears to be a significant statistical interaction between the proportion of pollution due to Chornobyl and the average cumulative dose of ^{137}CS (t = 2.07, p=0.039) reinforcing interference with sleep. In wave three, a basis function interacting with reconstructed revealed a complex five-way interaction that appeared to be statistically significantly interfering with sleep. The interaction entailed one or more death(s), air pollution in the previous wave, a lack of doctors visits, indication of positive symptoms (BSI) and some hostility (BSI). The effect was to enhance interference with sleep.

11.2 Potential sleep mediators

We discovered a number of variables that would intervene in the dose sleep relationship to influence sleep. For males, the potential mediators of the dose sleep relationship are several. In wave one, the self-perceived Chornobyl related health threat is a mediator. In wave two, age and injury to oneself because of Chornobyl are possible mediators. In wave three, injury to oneself continues to be a mediator, as does age, and the self-reported wave three illness count.

For women, there are several intervening variables that influence their sleep in wave one. Among them are anxiety from the basic symptom inventory (BSIanx), depression (BSIdep), PTSD in wave one, age, fear of going outdoors, fear of eating contaminated food, and the fact that they were injured as a result of Chornobyl, as well as the Chornobyl related health threat to the family.

In wave two, we observe that age, depression (BSI) continues to be an intervening variable, anxiety, concern about the percent of pollution due to Chornobyl, and the count of wave 2 illnesses, the perception of the Chornobyl related health threat to oneself and to their family.

In wave three, we can see that some of this is fading. Age seems to interfere with sleep as usual. Fear of eating contaminated food continues to interfere with sleep, as does depression (BSI), anxiety (BSI), the self reported status of physical health, the self-reported count of illnesses in wave three, perception of the Chornobyl related health threat to oneself and the family.

12 The Dose-Energy level Relationship in three waves

If does can affect pain and sleep, it would be surprising if did not have an effect on energy level as well. We examine nature of the dose-energy level relationship for direct, indirect, and interacting effects. Our models have the statistical power to detect small to medium effect sizes with as much as 40 parameters in the male model. Nonetheless, the male models reveal no significant dose - energy level response, even after trimming out the statistically nonsignificant parameters to endow the model with greater power, as shown in Table Five below.

Table5: Trimmed Regression Models of reconstructed dose on male energy level

	wave1	wave2	wave3
age	0.618***	0.244	0.082
	(0.179)	(0.151)	(0.141)
	0.001	0.106	0.559
educ2	28.609*	23.814	21.605
	(13.594)	(14.426)	(12.683)
	0.036	0.100	0.089
educ3	24.514*	20.903	20.896
	(12.148)	(13.889)	(11.800)
	0.044	0.133	0.077
educ4	16.351	17.502	18.785
	(12.804)	(14.435)	(12.487)
	0.202	0.226	0.133
educ5	28.903*	28.353*	26.735*
	(12.713)	(14.324)	(12.072)
	0.024	0.049	0.027
educ6	27.306*	22.599	23.612*
	(12.239)	(14.009)	(11.841)
	0.026	0.108	0.047
educ7	30.912	24.802	25.076
	(16.018)	(17.204)	(15.595)
	0.054	0.150	0.109

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marrw11	8.252		
	(6.390)		
	0.197		
marrw12	-21.773*		
	(9.477)		
	0.022		
marrw13	-2.683		
	(7.703)		
	0.728		
o.marrw14	0.000		
	(.)		
	.		
marrw15	23.106		
	(17.106)		
	0.178		
dvcew1	-35.614*		
(divorces)	(15.505)		
	0.022		
sepaw1	29.313		
(separations)	(15.124)		
	0.053		
shhlw1	-0.124*		
(hlth stresses	(0.061)		
and hassles)	0.042		
shhousw1	0.131*		
(housing hassles)	(0.059)		
	0.028		
phlthw1	-0.233*		
(physical hlth	(0.105)		
self-rpt)	0.026		
suprtw1	0.091		
	(0.055)		
	0.096		
fdferw1	0.072		
(fear of	(0.050)		
contamined food)	0.150		
healthef	0.605***	0.517***	0.449***
(health effects)	(0.144)	(0.101)	(0.130)
	0.000	0.000	0.001
carcin	-0.677***	-0.596***	-0.528***
(cancer rad risk)	(0.127)	(0.086)	(0.113)
	0.000	0.000	0.000
dafter	0.029**		
(Notification	(0.010)		
delay)	0.003		
near	-0.159***	-0.135**	-0.133**
	(0.044)	(0.043)	(0.043)
	0.000	0.002	0.002
chsize	-0.141**	-0.140**	-0.146**
(size of	(0.050)	(0.051)	(0.052)
disaster)	0.005	0.007	0.005
bfmEL2	-1.162*	-1.659**	-1.526**
	(0.512)	(0.527)	(0.538)
	0.024	0.002	0.005
bfmEL4	-0.453***	-0.383**	-0.383**
	(0.118)	(0.116)	(0.126)
	0.000	0.001	0.003

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avgcumdosew1	0.948		
	(1.058)		
	0.371		
marrw21		-6.680	
		(7.406)	
		0.368	
marrw22		-9.226	
		(9.357)	
		0.325	
marrw23		-13.393	
		(6.898)	
		0.053	
marrw25		-15.851	
		(10.922)	
		0.148	
radchw2		0.117*	
		(0.046)	
		0.011	
havmil		0.028	
		(0.023)	
		0.231	
bfmEL16		0.026	0.014*
		(0.016)	(0.007)
		0.094	0.037
suprtw2		0.067	
		(0.035)	
		0.056	
icdxcnt (medically diagnosed disease count)		3.038**	3.022**
		(0.987)	(0.986)
		0.002	0.002
avgcumdosew2		0.992	
		(1.063)	
		0.352	
emplw32			5.836
			(4.074)
			0.153
emplw33			4.134
			(4.757)
			0.385
emplw34			-5.318
			(4.594)
			0.248
radchw3			0.107*
			(0.048)
			0.025
avgcumdosew3			1.001
			(0.939)
			0.287
Constant	35384.229***	44177.838***	41521.571***
	(9604.502)	(9790.901)	(9861.935)
	0.000	0.000	0.000
adjR^2	0.350	0.361	0.350
BIC	3243.235	3240.196	3231.853
N	338	340	340

* p<0.05, ** p<0.01, *** p<0.001

Not only was there no apparent statistically significant main effect dose-energy level for men in wave three, there was no apparent statistically significant dose-energy level for women either (Table six). Other factors did affect the energy level as are indicated by the starred parameters below.

Table 6: Trimmed female energy level main effects regression models

	wave1	wave2	wave3
age	0.360*	-0.036	0.194
	(0.181)	(0.137)	(0.193)
	0.047	0.792	0.314
occ1w1	7.089		
	(5.484)		
	0.197		
occ2w1	14.470*		
	(6.327)		
	0.023		
occ3w1	10.897		
	(6.693)		
	0.104		
occ4w1	-4.146		
	(9.527)		
	0.664		
occ5w1	14.315		
	(7.756)		
	0.066		
occ6w1	7.316		
	(8.446)		
	0.387		
occ7w1	10.086		
	(7.097)		
	0.156		
occ8w1	18.404***		
	(5.530)		
	0.001		
aborw1	-3.437**		
	(1.197)		
	0.004		
sufamw1	0.140*		
	(0.056)		
	0.013		
mhlthw1	0.145*		
(mental hlth)	(0.068)		
	0.033		
polprw1	-0.070		
(effects of pol	(0.040)		
problems)	0.083		
BSIdep	0.870		
	(0.451)		
	0.055		
PTSDw1	0.129**		
	(0.045)		
	0.005		
BSIsoma	-2.981*		
	(1.439)		
	0.039		

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havmil	-0.017***	-0.014***	
	(0.004)	(0.003)	
	0.000	0.000	
bffel3	-5.830***	-2.713***	
	(1.594)	(0.376)	
	0.000	0.000	
bffel4	-0.532***	-0.527***	
	(0.086)	(0.088)	
	0.000	0.000	
chsize	0.116*	0.110*	0.161**
	(0.048)	(0.047)	(0.055)
	0.017	0.018	0.004
avgcumdosew1	-2.841		
	(2.488)		
	0.254		
polprw2		-0.102**	
		(0.034)	
		0.003	
HP2sxlife		12.525**	23.539***
		(4.089)	(4.573)
		0.002	0.000
avgcumdosew2		-0.426	
		(0.687)	
		0.535	
marrw31			-13.884
			(7.655)
			0.071
marrw32			-29.242***
			(8.260)
			0.000
marrw33			-7.126
			(6.227)
			0.253
marrw34			-5.494
			(10.101)
			0.587
marrw35			2.952
			(8.137)
			0.717
emplw32			-1.201
			(6.383)
			0.851
emplw33			34.167***
			(3.507)
			0.000
emplw34			8.436
			(4.916)
			0.087

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polprw3			-0.088*
			(0.042)
			0.036
fdferw3			0.200**
			(0.075)
			0.008
avgcumdosew3			-0.166
			(0.721)
			0.818
Constant	86.565*	68.670***	11.363
	(37.258)	(9.194)	(12.615)
	0.021	0.000	0.368
adjR^2	0.518	0.484	0.246
BIC	3432.834	3403.699	3564.524
N	362	363	363

* p<0.05, ** p<0.01, *** p<0.001

Among women, we observe that age can affect energy level, as can having a sales, as can having a technical, sales or administrative support (occ2w1) position or being a student at the time (occ8w1). Energy seems to improve with age but having an abortion in wave one (aborw1) can result in a decline in energy level for women. Family support (sufamw1) can also have a positive impact on energy level. However a belief that political problems can affect one (polprw1 and polprw3) can decrease the persona energy level. Self-reported post-traumatic stress syndrome (PTSDw1) significantly impacts energy level whereas somatization (BSIsoma) of illnesses is associated with a decline in energy level.

Residential distance from Chornobyl measured by the Haversine formula in miles (havmil) is significantly inversely related to energy level in waves two and three for women. Two basis functions (bffel3 and bffel4) are shown to have had a statistically significant effect as well. bffel3 is a recentering of the BSI somatic scale (bbel3= max(0, 23-BSIsoma) whereas bffel4 = max(0, phlthw3-40) is a recentering of self-reported wave three physical health, which is indicative change in physical health as compared to wave three.

Appreciation of the enormity of the Chornobyl disaster (chsize) persists in significance from wave two to wave three as a factor affecting energy level. Appreciation of the consequences of political problems can depress female energy levels in wave two. However, the sex life (HP2sxlife) can also positively affect the energy level as shown in waves two and three.

In wave three, cohabiting can result in a statistically significant decline in female energy level (marrw32). It is interesting tot note that fear of eating contaminated food persists into wave three (fderw3).

12.1 Moderation of the Dose Energy level relationship

When the main effects are not significant in a model, people often do not look to see if there are significant interactions that could potentiate the main effects into significance. In wave one, there were five interactions between variables and dose that had an effect on male energy level. Those variables were age, partner support, fear of eating contaminated food, belief that Chornobyl was the largest nuclear disaster, and count of medically diagnosed illnesses. Fear of eating contaminated food and age had a negative effect on the energy level, whereas the others had an overall positive effect.

By wave two, there were no statistically significant moderators.By wave three, the only possible moderator was the interaction of dose and the belief in the proportion of pollution that was due to Chornobyl. Those who believed that the proportion of pollution due to Chornobyl was low exhibited more energy level than other men.

The females exhibit no reliable moderating effects in waves one and two, or three.

12.2 Mediation of the Dose energy level relationship

If there is no statistically significant direct effect of average cumulative dose of ^{137}CS on the energy level of the respondent, is it possible that the dose - energy level relationship can be mediated by other variables? Our analysis shows that there are a variety of variables that might intervene in this relationship. Sleep (or lack thereof), when measured by the Nottingham subscale, can be seen to interfere with the dose-energy level relationship. Other mediating variables are anxiety (BSI), depression (self-reported), and Chornobyl related health threats can do so. For example, in wave one, male fear of going outside was a mediating or intervening variable.

During wave two, sleep as a mediator began to lose its statistical significance. Its significance faded into a status of being almost statistically significant at the .05 level ($p = 0.054$). However, age, as almost always, turns out to be a significant mediator ($p < 0.026$) in the dose-energy relationship. Sex life ($p < 0.031$) also appears to be able to statistically significantly interfere with sleep, according to a preliminary path analysis.

In wave three, age for men maintains its status as a mediating variable and sleep resumes its status as a mediator ($p = 0.026$). Sex life also maintains its status as a variable than can interfere with sleep. However, now the Chornobyl related health threat to the family becomes a significant intervening variable between dose and energy level ($p = .025$). The self-reported count of illnesses ($p = 0.028$) during wave three can also interfere with the dose sleep effect.

As for the females, there are seven variables that can be deemed to be mediators in wave one. Age, medically diagnosed illness count (icdxcnt), depression (BSI), anxiety measured both by the BSI and self-report, self-reported PTSDw1, sex life (Nottingham), and self-reported depression (depagw1) are shown to be possible mediators at wave one.

These findings summarize our findings regarding the main dose-psychological response sequelae of the Chornobyl disaster, suggested in part one of hypothesis one of our proposal.In the next section, we will address part two of hypothesis one, where we address the impacts on activities of daily life.

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