Risk Factors for Long-term Mental and Psychosomatic Distress in Latvian Chernobyl Liquidators

Jean-François Viel,1 Elvira Curbakova,2 Baiba Dzerve,2 Maija Eglite,3 Tija Zvagule,2 and Claude Vincent1

1Faculty of Medicine, Department of Public Health, Besançon, France; 2Paul Stradins State Hospital, Riga, Latvia; 3Medical Academy of Latvia, Institute of Labour Medicine, Riga, Latvia

Epidemiologic studies on the health effects of the Chernobyl disaster have focused largely on physical health, whereas the psychological consequences have received little attention. The authors have assessed the associations of various exposure variables with mental and psychosomatic distress in a sample of 1412 Latvian liquidators drawn from the State Latvian Chernobyl Clean-up Workers Registry. The outcome was a mixed mental–psychosomatic disorder occurring during 1986 to 1995. Comparisons among subgroups of the cohort classified according to exposure type or level were based on the proportional hazards model. Length of work (≥28 days) in a 10 km radius from the reactor (relative risk (RR) = 1.39, 95% confidence interval [CI] 1.14–1.70), work (≥1 time) on the damaged reactor roof (RR = 1.46, 95% CI 1.02–2.09), forest work (RR = 1.41, 95% CI 1.19–1.68), and fresh fruit consumption (≥1 time/day) (RR = 1.72, 95% CI 1.12–2.65) are risk factors for mixed mental–psychosomatic disorder. Construction of the sarcophagus (RR = 1.82, 95% CI 0.89–3.72) is also associated with this outcome, although nonsignificantly. Distinguishing stress-related from radiation-induced effects in this data set was difficult and these findings should provide a basis for later hypothesis testing in other cohorts. — Environ Health Perspect 105(Suppl 6):1539–1544 (1997)

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Introduction

The most serious reactor accident in the history of nuclear power occurred 26 April 1986, when the Chernobyl No. 4 reactor exploded. After the initial explosion, the reactor burned for 10 days, releasing 3 to 4% of the total radioactivity in the reactor core to the atmosphere (1). Agricultural products were contaminated because of the deposition of radioactive compounds on the ground and the uptake by plants and animals. The absorption of radionuclides from ingestion of contaminated food and water and through inhalation may have resulted in serious internal exposure. Of particular concern for medium- and long-term effects is caesium-137, among the main radionuclides in the fallout.

The consequences attributed to the accident at the Chernobyl nuclear power plant have been subjected to extensive scientific examination, but epidemiologic studies on health effects have focused largely on physical health. Except for a marked increase in the incidence of thyroid cancers in children, epidemiologic evidence presently available is weak with regard to somatic consequences (2–5). A decade has passed since the accident, but this is a relatively short time span within which to adequately document the risk of chronic conditions. Moreover, a problem encountered in low-dose studies is that the magnitude of potential confounding effects may be greater than the magnitude of the radiation effects.

On the other hand, little attention has been paid to the impact of the accident on the mental health of populations. According to Havenaar et al. (6), the Chernobyl nuclear disaster may be partly responsible for the high prevalence of (low severity) psychiatric disorders and psychologic distress in the Gomel region (Republic of Belarus). Nevertheless, to our knowledge no detailed results have been reported to date on exposures or habits hypothesized to increase the risk for mental disorders in the aftermath of the accident.

Many people (approximately 135,000) were evacuated from inside a 30 km radius of Chernobyl some days after the catastrophe because they were considered to be highly exposed. Long-term cohort studies that include all persons who lived in this affected area are impractical, because of the difficulty and high costs of obtaining data for such studies. However, some people were deliberately sent to this area to perform clean-up work after the disaster. Some of these workers participated in the construction of a massive structure in concrete and steel used to support what remained of the walls of the reactor building. Sarcophagus was the name given to this containment structure. These clean-up workers, often called liquidators or rectifiers, numbered between 600,000 and 800,000, and likely have been highly exposed to radiation. Supposedly they have had the state of their health monitored and registered, at least in a more thorough way than most of the general population (7).

Hence, studying liquidator cohorts is an important way (if not the only way) to assess whether psychological distress and/or psychiatric disorders are related to radiation exposure after the Chernobyl accident.

Among the liquidators of various nationalities, 4665 male residents of Latvia have been traced in extensive research carried out by a nationwide registry (established in 1987 to register all health events occurring in the Latvian clean-up worker population) and followed since that time. On the basis of this well-defined liquidator cohort, our objective is to examine the extent to which certain exposure circumstances (e.g., work characteristics, nutritional habits) represent risk factors for mental and psychosomatic distress.

Population and Methods

For all 4665 male liquidators, a basic questionnaire on administrative characteristics
and clinical features was filled out during their annual examination in outpatient clinics. Questionnaires are centralized, compiled, reviewed for completeness, accuracy, redundancy, and stored by the registry staff in Riga.

The psychopathology syndromes on which we focus in this study are depression, anxiety, and somatization. They have been prospectively diagnosed and coded as any health event with the International Classification of Diseases, 9th revision (ICD-9) by well-trained physicians in charge of the liquidator follow-up in Latvia. We have retained three outcomes in a first step: depression (neurotic depression and brief depressive reaction) (ICD-9, Codes 300.4 and 309.0), cardiovascular physiologic malfunction arising from mental factors (ICD-9, Code 306.2), and unspecified disorders of the autonomous nervous system (ICD-9, Code 337.9). Although the two depression codes probably are familiar to Western psychiatric audiences, the other two codes are not and usually are classified as some form of anxiety or psychosomatic disorder using any of the modern psychiatric instruments. Hence, we have grouped all the categories together, yielding a mixed mental–psychosomatic disorder. Anxiety, posttraumatic stress disorder, and sleep disturbance could not be studied individually because of the coding scheme (lack of ICD codes or disease codes preferred to symptom codes for given cases). A liquidator was considered to suffer from such a mental–psychosomatic disorder if the latter was observed at least once during successive clinical examinations. If the same pathology occurred several times in the same patient, only the first event (with its date of occurrence) was considered. Person-years at risk were calculated from the date of arrival in the Chernobyl area. For liquidators lost to follow-up, observations were censored at the date when the subject was last known to have undergone a clinical examination. The cutoff date for pathology occurrence was 30 June 1995.

At the beginning of the registration process, no attempt was made to record detailed data on various exposures and risk factors. It was decided in the second stage, however, to have the clean-up workers address these issues retrospectively by answering a detailed questionnaire. Because of economic difficulties faced by Latvia at that time, it was not possible to conduct this survey before 1994. Furthermore, the grant devoted to this task allowed completion of only about 1500 questionnaires. So a subsample was drawn that included on a systematic basis the first 1444 liquidators to undergo their annual medical examination in 1994. This sampling frame depended, therefore, on neither current or previous health status, level of anxiety, nor the amount of radiation exposure. Information was elicited from the corresponding questionnaires during this medical check. Questions were asked about medical history, lifestyle, and occupational and environmental risk factors. All variables that could be considered surrogates of ionizing radiation exposure as well as some confounding factors were considered in this study. This yielded a set of the following 22 items: length of stay in the Chernobyl area, length of work in various places (on the damaged reactor, in the inner zone 0–10 km), number of times liquidator has worked on the damaged reactor roof, types of work (construction of the sarcophagus, soil removal, building construction or destruction, work in the forest, transport, chemical exposure), protective habits (gloves, breathing apparatus, protective clothing, showers), local food consumption (water, milk, fresh vegetables, fresh fruits, fresh mushrooms, meat), and smoking habits. A major problem in such environmental contamination is that valid and reliable measurements of radiation exposure (either external or internal) generally are not available. In our sample, 922 liquidators had some dose estimates on their military identity cards. But this information was unreliable, because it is well known that the former Red Army distorted these data on purpose. Hence, we have decided a priori to discard these estimates.

The objective of a cohort study generally is to estimate the risks of various diseases among people followed after exposure relative to background risks among persons not exposed to the same environmental factors. However, this requires comparisons with prevailing rates in the national population, which unfortunately were not available in Latvia. Hence, we have adopted another analysis design, i.e., comparisons between subgroups of the cohort classified according to exposure type or level. This approach has the advantage of allowing estimation of exposure–response relationships, one major argument in a causal inference process. Analyses were based on the proportional hazards model, in which the variable of interest is the length of time that elapses before the event (pathology) occurred for the first time (i.e., survival time) (8). Estimates of relative risks (RRs) were adjusted by stratification for age and calendar period. A set of dummy variables was generated for each categorical scaled variable using the lowest category as the reference group. The original coding scheme was kept except for food consumption, for which six levels were aggregated in four final categories (no consumption, one to three times per month, one to six times per week, one or more times per day). The length of stay in the Chernobyl area was divided into quartiles. The other continuous scaled variables (length of work, number of times on the reactor roof), which were all ununiformly distributed, initially were separated into three categories, the first class corresponding to zero and the next two classes separated by the median of the remaining values. Finally, age range was split into five levels (25, 25–34, 35–44, 45–54, ≥55 years of age), and calendar period in two categories (1986 and later). A two-stage procedure was used. The first stage consisted of analyzing all the variables in turn (univariate analysis). In the second stage, all the variables with p values lower than 0.20 were introduced simultaneously in a multivariate model. Ninety-five percent confidence intervals (CI) were estimated for each category except reference categories. All analyses were performed with the BMDP computer package (BMDP Software, Los Angeles, CA) (module 2L).

Results

Among the 1444 Chernobyl liquidators from the subcohort, 31 were withdrawn from the analysis because of missing data, and a further one because he represented on his own a stratum without any health event under study.

In addressing the representativeness of the final 1412-liquidator sample considered in this study, we were faced with a paucity of data in the whole cohort. The only reliable variables were calendar year of arrival at Chernobyl and age at arrival in the Chernobyl area. Breakdowns for both the study population and the remaining population are reported in Table 1. There is no significant difference between distributions either for year of arrival ($\chi^2_{3,df} = 5.59, p = 0.13$) or age ($\chi^2_{3,df} = 5.08, p = 0.17$).

A total of 615 mixed mental–psychosomatic disorders was ascertained. Risk factors for this outcome, estimated from univariate analyses, are reported in Table 2. The length of work in the 10-km radius from the nuclear plant is associated with an increased risk ($p = 0.002$), the highest category (more
thans or equal to 28 days) showing an RR of 1.34 (95% CI 1.11–1.62, \( p < 0.01 \)). Having worked more than one time on the damaged reactor roof appears also to be a significant risk factor (RR = 1.44, 95% CI 1.02–2.04, \( p < 0.05 \)). No protective habits were associated with the frequency of the outcome. Among the different types of work, one is highly significant—forest work (RR = 1.43, 95% CI 1.22–1.69, \( p < 10^{-4} \)). Three local food consumption items are significant risk factors with an apparent dose-response pattern—fresh fruit (\( p = 0.01 \)), fresh vegetables (\( p = 0.05 \)), and meat (\( p = 0.01 \)). For all of the latter, consumption once or more per day is at high risk (\( p < 0.001 \), \( p < 0.01 \), and \( p < 0.01 \), respectively). Finally, tobacco consumption does not appear to be a risk factor.

The nine variables exhibiting \( p \) values lower than 0.20 were then introduced in a multivariate model (Table 3). Four remained statistically significant: length of work in the 10-km radius (\( p = 0.002 \)), work on the reactor roof (\( p = 0.05 \)), forest work (\( p < 10^{-4} \)), and consumption of fresh fruit (\( p = 0.05 \)).

The highest RR was found for the latter; consuming fresh fruits once or more per day multiplied the risk of subsequent mental and psychosomatic disorders by 1.72 (95% CI 1.12–2.65, \( p < 0.02 \)). The risk associated with staying in the Chernobyl zone 28 days or more is of the same magnitude as for the univariate analysis (RR = 1.39, 95% CI 1.14–1.70, \( p < 0.01 \)). The same occurs for work on the reactor roof (RR = 1.46, 95% CI 1.02–2.09, \( p < 0.05 \)) and forest work (RR = 1.41, 95% CI 1.19–1.68, \( p < 10^{-4} \)).

Construction of the sarcophagus also appears to be a risk factor (RR = 1.82), although it is not significant (\( p = 0.10 \)).

### Discussion

The lack of research on man-made disasters that have occurred has recently been recognized (9). We are not aware of any

### Table 1. Breakdown by calendar year or age of liquidators at their arrival in the Chernobyl area.

| Characteristic       | Study sample (n = 1412) | Remaining cohort population (n = 3253) |
|----------------------|-------------------------|---------------------------------------|
| Year of arrival\( a \) |                         |                                       |
| 1986                 | 83 (59.3%)              | 1842 (56.6%)                          |
| 1987                 | 396 (28.2%)             | 973 (29.3%)                           |
| 1988                 | 147 (10.4%)             | 340 (9.7%)                            |
| later                | 29 (2.1%)               | 90 (3.0%)                             |
| Age\( b \)           |                         |                                       |
| < 25                 | 261 (18.5%)             | 677 (20.8%)                           |
| 25–34                | 670 (47.4%)             | 1530 (47.0%)                          |
| 35–44                | 432 (30.6%)             | 958 (29.5%)                           |
| 45 +                 | 49 (3.5%)               | 87 (2.7%)                             |

\( x_1^2 = 5.59, p = 0.13 \). \( x_2^2 = 5.08, p = 0.17 \).

### Table 2. Univariate analysis\( a \) of risk factors for mental and psychosomatic distress in 1412 Latvian Chernobyl clean-up workers.

| Variable                                      | Levels | Relative risk | 95% CI | \( p \) Value |
|-----------------------------------------------|--------|---------------|--------|--------------|
| Duration of presence and work                 |        |               |        |              |
| Length of stay in Chernobyl area, weeks       | 0–8    | 1             |        | 0.36         |
|                                              | 8–11.3 | 1.10          | 0.88–1.38 |
|                                              | 11.3–16.1 | 0.96 | 0.76–1.22 |
|                                              | ≥16.1  | 1.15          | 0.92–1.46 |
| Length of work\( b \), day                    | 0      | 1             |        | 0.002        |
|                                              | 0–28   | 1.00          | 0.82–1.22 |
|                                              | ≥28    | 1.34          | 1.11–1.62 |
| Work on reactor roof, number of times         | 1      | 0.87          | 0.64–1.18 |
|                                              | >1     | 1.44          | 1.02–2.04 |
| Length of work on reactor\( b \), days        | 0      | 1             |        | 0.66         |
|                                              | 0–0.71 | 1.09          | 0.90–1.32 |
|                                              | ≥0.71  | 1.00          | 0.82–1.23 |
| Protective habits                             |        |               |        |              |
| Breathing mask                                 | Never  | 1             |        | 0.13         |
|                                              | Seldom | 0.84          | 0.67–1.06 |
|                                              | Often  | 1.02          | 0.81–1.27 |
|                                              | Always | 1.10          | 0.87–1.38 |
| Protective clothes                            |        |               |        |              |
|                                              | Never  | 1             |        | 0.40         |
|                                              | Seldom | 0.85          | 0.65–1.11 |
|                                              | Often  | 1.09          | 0.81–1.46 |
|                                              | Always | 1.12          | 0.88–1.42 |
| Gloves                                        |        |               |        |              |
|                                              | Never  | 1             |        | 0.41         |
|                                              | Seldom | 0.87          | 0.69–1.09 |
|                                              | Often  | 1.07          | 0.84–1.37 |
|                                              | Always | 1.11          | 0.86–1.44 |
| Shower                                        |        |               |        |              |
|                                              | Never  | 1             |        | 0.70         |
|                                              | Sometimes | 0.93 | 0.60–1.45 |
|                                              | Frequently | 1.00 | 0.64–1.56 |
| Type of work                                  |        |               |        |              |
| Construction of the sarcophagus               | No     | 1             |        | 0.09         |
|                                              | Yes    | 1.81          | 0.89–3.66 |
| Soil removal                                  | No     | 1             |        | 0.67         |
|                                              | Yes    | 1.03          | 0.88–1.21 |
| Buildings destruction                         | No     | 1             |        | 0.52         |
|                                              | Yes    | 1.07          | 0.88–1.30 |
| Buildings construction                        | No     | 1             |        | 0.67         |
|                                              | Yes    | 1.05          | 0.83–1.34 |
| Forest work                                   | No     | 1             |        | <10^-4       |
|                                              | Yes    | 1.43          | 1.22–1.69 |
| Transport                                     | No     | 1             |        | 0.96         |
|                                              | Yes    | 1.00          | 0.86–1.18 |
| Chemical exposure                             | No     | 1             |        | 0.44         |
|                                              | Yes    | 0.93          | 0.78–1.11 |
| Local food consumption                        |        |               |        |              |
| Water                                         | 0      | 1             |        | 0.88         |
|                                              | 1–3/month | 0.92 | 0.46–1.86 |
|                                              | 1–6/week | 1.15 | 0.79–1.67 |
|                                              | ≥1/day | 1.03          | 0.84–1.26 |
| Milk                                          | 0      | 1             |        | 0.76         |
|                                              | 1–3/month | 0.88 | 0.33–2.35 |
|                                              | 1–6/week | 1.04 | 0.60–1.80 |
|                                              | ≥1/day | 1.26          | 0.81–1.95 |
| Fresh fruit                                   | 0      | 1             |        | 0.01         |
|                                              | 1–3/month | 1.08 | 0.82–1.41 |
|                                              | 1–6/week | 1.04 | 0.64–1.27 |
|                                              | ≥1/day | 1.54          | 1.16–1.99 |
| Fresh vegetables                              | 0      | 1             |        | 0.05         |
|                                              | 1–3/month | 1.02 | 0.72–1.43 |
|                                              | 1–6/week | 1.10 | 0.88–1.38 |
|                                              | ≥1/day | 1.48          | 1.12–1.96 |

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Table 2. (Continued)

| Variable            | Levels | Relative risk | 95% CI  | p Value |
|---------------------|--------|---------------|---------|---------|
| Fresh mushrooms     | 0      | 1             | —       | 0.65    |
|                     | 1–3/month | 0.98       | 0.70–1.36 |         |
|                     | 1–6/week   | 1.27       | 0.86–1.89 |         |
|                     | ≥1/day     | 1.13       | 0.69–1.87 |         |
| Meat                | 0      | 1             | —       | 0.01    |
|                     | 1–3/month | 1.22       | 0.54–2.72 |         |
|                     | 1–6/week   | 1.40       | 0.79–2.49 |         |
|                     | ≥1/day     | 1.64       | 1.21–2.24 |         |
| Tobacco consumption | Never     | 1            | —       | 0.16    |
|                     | Sometimes  | 0.89       | 0.75–1.05 |         |
|                     | Frequently | 1.10       | 0.89–1.37 |         |

*Stratified for age and period of arrival at Chernobyl. 10-mile radius from reactor.

Table 3. Multivariate analysis of risk factors for mental and psychosomatic distress in 1412 Latvian Chernobyl clean-up workers.

| Variable                        | Levels | Relative risk | 95% CI  | p value |
|---------------------------------|--------|---------------|---------|---------|
| Length of work<sup>3</sup>, day | 0–28   | 1.04          | 0.84–1.28 | 0.002   |
|                                | ≥28    | 1.39          | 1.14–1.70 |         |
| Work on reactor roof, number of | 0      | 1             | —       | 0.05    |
| times                           | 1      | 0.84          | 0.62–1.15 |         |
|                                | >1     | 1.46          | 1.02–2.09 |         |
| Breathing mask                  | Never  | 1             | —       | 0.15    |
|                                | Seldom | 0.83          | 0.65–1.05 |         |
|                                | Often  | 1.00          | 0.79–1.26 |         |
|                                | Always | 1.07          | 0.83–1.37 |         |
| Construction of the sarcophagus | No     | 1             | —       | 0.10    |
|                                | Yes    | 1.82          | 0.89–3.72 |         |
| Forest work                     | No     | 1             | —       | <10<sup>−4</sup> |
|                                | Yes    | 1.41          | 1.19–1.68 |         |
| Fresh fruit consumption         | 0      | 1             | —       | 0.05    |
|                                | 1–3/month | 1.10       | 0.80–1.50 |         |
|                                | 1–6/month | 0.90       | 0.68–1.19 |         |
|                                | ≥1/day  | 1.72          | 1.12–2.65 |         |
| Fresh vegetables consumption    | 0      | 1             | —       | 0.37    |
|                                | 1–3/month | 0.92       | 0.62–1.36 |         |
|                                | 1–6/month | 1.23       | 0.89–1.70 |         |
|                                | ≥1/day  | 0.77          | 0.44–1.33 |         |
| Meat consumption                | 0      | 1             | —       | 0.65    |
|                                | 1–3/month | 1.18       | 0.50–2.74 |         |
|                                | 1–6/month | 1.32       | 0.72–2.42 |         |
|                                | ≥1/day  | 1.25          | 0.81–1.92 |         |
| Tobacco consumption             | Never  | 1             | —       | 0.26    |
|                                | Sometimes | 0.90       | 0.76–1.07 |         |
|                                | Frequently | 1.09       | 0.88–1.35 |         |

*Stratified for age and period of arrival at Chernobyl. 10-mile radius from reactor.

other published study highlighting risk factors associated with specific mental syndromes in the aftermath of the Chernobyl catastrophe. In the Latvian cohort, the length of stay in the Chernobyl area, the length of work in the inner zone (< 10 km), the number of times the liquidator worked on the damaged reactor roof, and high consumptions of fresh fruits are risk factors for mixed mental–psychosomatic disorder.

We have attempted to design this disaster study with great attention to basic epidemiologic principles, i.e., sample representativeness, systematic and reliable outcome measures, multivariate analysis of exposure effects while taking into account some risk factors. However, we had to cope with tough postdisaster conditions and major financial constraints that prevented us carrying out the optimal survey we had envisioned.

Thus, this study has two main limitations. First, the subcohort can only be considered representative (according to age and calendar year of arrival at Chernobyl) of liquidators who have survived at least 8 years after the catastrophe, since risk factors were assessed in 1994. Nevertheless, a few deaths have occurred among the whole cohort during the time interval (91 deaths). Second, exposure surrogates were collected after most of the events under study had occurred, so one cannot rule out a recall bias. Liquidators suffering from mental disorders could have exaggerated the level of their exposures, which was retrospectively assessed. But many risk factors could be considered as fairly reliable, as they are factual (e.g., type of work) or reconstructed from spatial or temporal information (length of residence or work) that has been checked through individual Chernobyl passports or in service records.

The relevance and the reliability of outcome measures must be addressed. We were forced to rely on clinically significant morbidity classified according to the ICD-9 to assess level of mental distress because this is the only measure available. ICD-9 may appear crude compared to more refined diagnostic instruments such as the Diagnostic Interview Schedule, the Brief Symptom Inventory, the Post Traumatic Stress Disorder Reaction Index, or the Impact of Events Scale (10), but one must keep in mind the chaotic and uncertain conditions that prevailed at the beginning of the liquidators health monitoring, and that their follow-ups do not focus solely on mental disorders. As a result, no methods for assessing stress exposure have been employed. In practice, in the Russian ICD-9 version both 306.2 and 337.9 codes refer to similar symptoms of various types (physical and neurological) that may be psychogenic in origin (11). An additional advantage is that the ICD-9 is standardized and familiar to all the involved physicians, who had regular meetings to agree on coding procedures. By defining a broad group we have attempted to identify mixed mental–psychosomatic disorders (the predominant medical disorder seen in community surveys) and to gain some statistical power. Moreover, we did not know whether or not physicians attributed the mental health effects under study to radiation exposure.

Proxy measures for radiation exposure are entered separately in the statistical models, and it is possible that a total exposure index that combines the measures in some way might have been preferable. The association between official doses and characteristics of work as a Chernobyl liquidator has been examined in a pilot study (12). Results indicate that some characteristics such as duration of work in the 30-km area, radiation exposure, and other variables have been included in the final model.
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zone may not be correlated with radiation dose, whereas other characteristics such as working within 500 m of the reactor, on the roof of the reactor, or on the construction of the sarcophagus are associated with doses recorded in the Chernobyl Registry. Additional research on a larger and more detailed database clearly is warranted before the construction and epidemiologic use of a gradient of probable individual exposures.

In this cohort study, status can be determined only through health examinations of the individuals, with the time at which a pathology first occurs only being determined to be in the time interval between the last examination without a disease and the first examination with a disease. Such data are then interval-censored rather than right-censored. But it has been demonstrated that the estimated effects of the covariates are not very sensitive to how time was dealt with in the analyses (13). One must also bear in mind that some chance findings are likely due to multiple comparisons, although several p values are lower than 0.01.

Distinguishing stress-related from radiation-induced effects is difficult in this data set because there is no actual measure of the liquidators perceptions or stress level, and moreover, some retrospective assessments of exposure could be beset by recall bias. However, it seems likely that most of the significant risk factors correspond to some extent to the perceived degree of radioactive contamination, rather than the level of contamination itself.

The length of work time in the inner zone (<10 km from the reactor) obviously was considered a high risk factor by the liquidators (living or working so close to the damaged reactor); the same goes for the number of times on the reactor roof (at least by young soldiers carrying burning pieces of graphite from the reactor with their bare hands). In our study, having worked on the sarcophagus is a risk factor, although it is not statistically significant (p = 0.10). In this case also, though, liquidators could reasonably suppose exposure to radiation probably was high.

On the other hand, forest work could possibly be another mechanism of exposure. Because of the high filtering characteristics of trees, the specific ecological pathways in forests when contaminated often result in enhanced retention of contaminating radionuclides. As a result, lichens and mosses often exhibited high concentrations of radionuclides (14). Hence, forests are a potential reservoir of secondary contamination and fires represent a potential risk of resuspension of radionuclides. So in the wake of the Chernobyl accident, it became apparent that forest ecosystems are very important sources of radiation doses to humans that demand careful management (15). These technical considerations probably escaped the liquidators' attention (hence avoiding recall bias), and could to some extent favor radiation-induced effects. When one considers the close relationships between neuroendocrine dysfunctions and mental disorders, especially in the hypothalamic–pituitary–adrenal axis (16), one wonders whether they could represent potential pathways for radiation to have an impact on mental abilities. However, given our limited biochemical understanding of radiation and stress effects, and because of the limitations of this epidemiologic survey, which was not originally designed to explain the complex pathway between Chernobyl exposures and psychological morbidity, the findings about forest work should serve as a basis for later hypothesis testing in other cohorts before any firm conclusions are reached.

We are hesitant to interpret the fresh fruit consumption data. Of course, radioactive contamination has entered the soil and the food chain. However, other food items such as milk and water do not appear to be risk factors and questions about their local origin and frequency of consumption raise concerns about the interpretation of our results. Furthermore, a threshold (daily consumption) is emphasized rather than a dose–response pattern.

On the whole, this work highlights some risk factors for mental and psychosomatic disorders among Latvian clean-up workers after the Chernobyl accident. Possible pathways include: radiation causing physical disorders that in turn cause psychiatric disorders; radiation exposure causing increased anxiety about health, which in turn leads to psychiatric disorders; and psychiatric disease induced by direct radiation. In attempting to generalize these findings across liquidator cohorts, it is necessary to bear in mind some critical characteristics as the societal response to their health needs or the social and family support which could alleviate the mental deleterious effects caused by such a disaster, but which can operate variously in different demographic groups (10). More research is clearly needed on the long-term mental health consequences of the Chernobyl disaster. The follow-up of Latvian liquidators is continuing and should contribute to evaluations of the extent of psychopathology during different phases of the aftermath. In such human-made disasters, in which the more extreme health consequences may take years to develop, the level of mental disorders may not abate over time. Another avenue of research consists of the mechanisms by which a nuclear disaster leads to mental health effects. Multidisciplinary cooperation (cognitive and psychosocial sciences, molecular biology, epidemiology) is warranted to assess individual attitudes and fears about radiation and then to distinguish psychogenic effects from bioeffects of organic origin. However, whether stress-related or radiation-induced, mental distress reflects a genuine human suffering to be taken account of and appears to be an important health consequence of the Chernobyl nuclear accident in view of the size of the population affected and the burden on the health care systems.

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