

## ・ 不眠とは？

- 社会生活に支障があり、自覚的にも悩んでいる状態です。睡眠時間が短くても本人が満足し、昼間に正常な活動ができるならば、問題ありません。
- 必要な睡眠時間が量的・質的に低下します。
  - ・ 床についてから30分～1時間以上寝つけない（入眠障害）
  - ・ 夜中に何度も目が覚める。再び眠るまでに時間がかかる（中途覚醒）
  - ・ 予定の起床時間より2時間以上早く目が覚める（早期覚醒）
  - ・ ぐっすり眠ったという感じが得られない（熟眠障害） など

## ・ 結果の診断

- 点数0～5点だった人  
不眠症の可能性は低いと思われます。今の生活を続けて下さい。
- 点数が6点以上だった人  
不眠症の可能性ががあります。16～18頁を参考に、できそうなことを試してみましょう。強い不眠が2週間続く場合には、健康管理室にご相談下さい。

## • お酒の量が増加すると？

- 肝臓に中性脂肪が蓄積され、大きな負担をかけることとなります。
- 胃や腸といった消化管の粘膜も荒れてきます。
- 血圧が急激に高くなります。
- 依存症になる可能性もあります。



## • 結果の診断

- 点数が0～1点だった人

アルコールに依存している可能性は低いと思われます。今の生活を続けて下さい。

- 点数が2～3点だった人

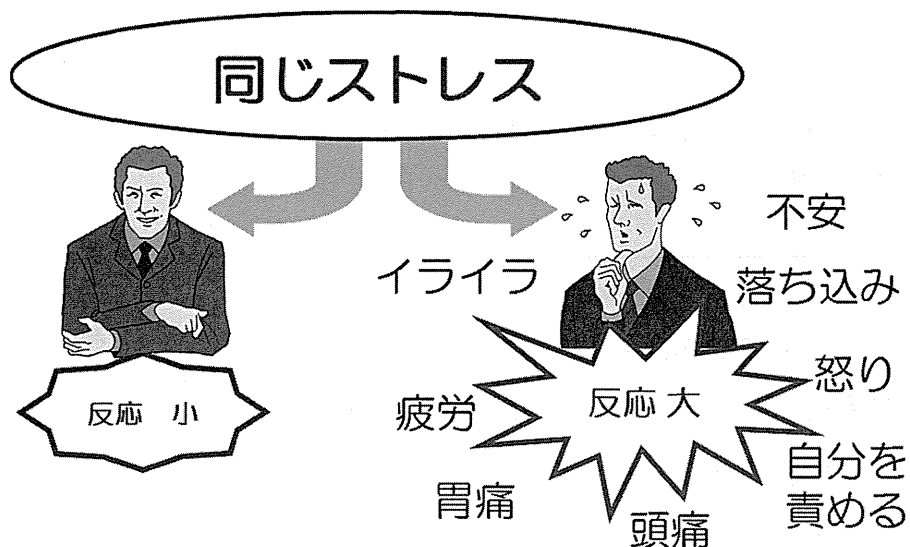
アルコールに依存している可能性があります。週2日は休肝日にしたり、食べながら適量範囲でゆっくりと飲みましょう。寝つくための飲酒も避けましょう。11頁のストレス対処法や13頁のリラックス法などを参考に、お酒以外の方法でストレスを発散させましょう。

- 点数が4点以上だった人

アルコールに依存している可能性が高いと考えられます。健康管理室で相談することをお勧めします。

### 3. ストレス対処の方法

- ストレス対処とは、ストレスを受けても上手く対処すること、ストレス反応を大きくしないことを言います。
- 同じストレスを受けても、すべての人が同じように落ち込んだり、イライラするわけではありません。人によって、ストレスの受け止め方（認知）やストレス対処の方法が違うからです。
- まずは、次頁で自分のストレス対処のタイプを調べてみましょう。



セルフ  
チェック

## あなたのストレス対処法は？

あなたはストレスを受けた時に、どのように考え、行動しますか？  
当てはまるものに○をつけて下さい。

|   |                         |
|---|-------------------------|
| <ul style="list-style-type: none"> <li>• 詳しい人から自分に必要な情報を収集する ( )</li> <li>• 既に経験した人から話を聞いて参考にする ( )</li> <li>• 力のある人に教えを受けて解決しようとする ( )</li> </ul>  | 情報収集型<br><u>○の数</u> つ   |
| <ul style="list-style-type: none"> <li>• 原因を検討し、どうするべきかを考える ( )</li> <li>• 過ぎたことを反省し、次にすべきことを考える ( )</li> <li>• どのような対策をとるべきか綿密に考える ( )</li> </ul>  | 計画立案型<br><u>○の数</u> つ   |
| <ul style="list-style-type: none"> <li>• 悪い面ばかりでなく、良い面を見つけていく ( )</li> <li>• 今後は良いこともあるだろうと考える ( )</li> <li>• 悪いことばかりではないと、楽観的に考える ( )</li> </ul>   | 肯定的解釈型<br><u>○の数</u> つ  |
| <ul style="list-style-type: none"> <li>• 誰かに話を聞いてもらい、冷静さを取り戻す ( )</li> <li>• 誰かに話を聞いてもらい、気を静めようとする ( )</li> <li>• 誰かに愚痴をこぼして、気持ちをほらす ( )</li> </ul> | カタルシス型<br><u>○の数</u> つ  |
| <ul style="list-style-type: none"> <li>• 責任を他の人に押しつける ( )</li> <li>• 自分は悪くないと言いのがれする ( )</li> <li>• その場を取り繕って、その状況から一時避難する ( )</li> </ul>           | 責任転嫁型<br><u>○の数</u> つ   |
| <ul style="list-style-type: none"> <li>• 対処できない問題だと考え、あきらめる ( )</li> <li>• どうすることもできないと解決を先のばしする ( )</li> <li>• 自分では手におえないと考え、放棄する ( )</li> </ul>   | 放棄あきらめ型<br><u>○の数</u> つ |
| <ul style="list-style-type: none"> <li>• そのことをあまり考えないようにする ( )</li> <li>• 嫌なことを頭に浮かべないようにする ( )</li> <li>• 無理にでも忘れようとする ( )</li> </ul>              | 回避的思考型<br><u>○の数</u> つ  |
| <ul style="list-style-type: none"> <li>• 友達とお酒を飲んだり、好物を食べたりする ( )</li> <li>• スポーツや旅行などで、活動的に過ごす ( )</li> <li>• 散歩や音楽鑑賞などで、のんびり過ごす ( )</li> </ul>    | 気晴らし型<br><u>○の数</u> つ   |

## (1) 積極的対処 (〇の数 つ)

- 情報収集型：困った時に周囲の人に助言を求めたり、色々な情報を集める。
- 計画立案型：直面している問題を積極的に解決しようとする。
- 肯定解釈型：出来事の良い面をみたり、楽観的な考え方をする。
- カタルシス型：自分の抱えている悩みを誰かに聞いてもらったり、愚痴をこぼしたりすることで、心を浄化（カタルシス）する。

・ストレスになる状況や問題を避けて、積極的に対処する方法で、ストレスを減らすことが分かっています。周囲に助言を求めたり、悩みを聞いてもらうことは、弱音をはいているわけではなく、重要な対処方法なのです。

・しかし、積極的に解決しようと頑張りすぎると燃え尽きてしまう（バーンアウト）こともありますので、気をつけましょう。

## (2) 消極的対処 (〇の数 つ)

- 責任転嫁型：つらい出来事や困難な状況から逃げ出したり、自分のせいにしないで眼をそらす。
- 放棄あきらめ型：問題の解決を見送り、状況に身をまかせる。
- 回避思考型：問題から距離をおき、思い出さないようにする。
- 気晴らし型：趣味などを行い、気晴らしをする。

・ストレスになる状況や問題を避けて、消極的に対処する方法です。一時的にストレスを減らしますが、問題は解決していないため、結局ストレスは残ったままです。また職場内での責任転嫁はぎすぎすした雰囲気を引き起こします。

・しかし、長期化した問題や必要以上の負担がある場合、ストレスを一時的に減らすためには、消極的対処が役立ちます。

(1) と (2) の〇の数が、

- ・同じくらい・・・バランス良いストレス対処です。
- ・極端に差がある・・・バランス良いストレス対処を心がけましょう。

# あなたのリラックス法は？

- 人には、自律神経（交感神経と副交感神経）があります。交感神経の働きが高いと緊張・ストレスが高い状態、副交感神経の働きが高いとリラックスしている状態です。
- 交感神経の高い状態が続くと、心身に不調が生じます。そのため、リラックスする時間を作りましょう。



- スポーツや旅行など活動的な趣味、散歩や音楽鑑賞や園芸などのんびり過ごす趣味など、自分の好きなことに集中できる時間を確保しましょう。
- 活動的な趣味は、疲れている時はかえって疲労をためます。のんびりリラックスできる趣味も持つことを心がけましょう。

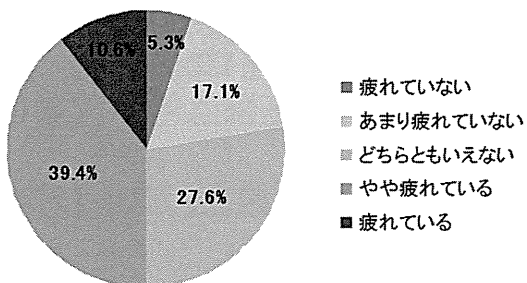


図2 勤務日の疲労感

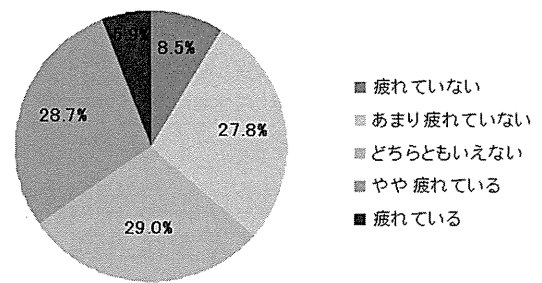
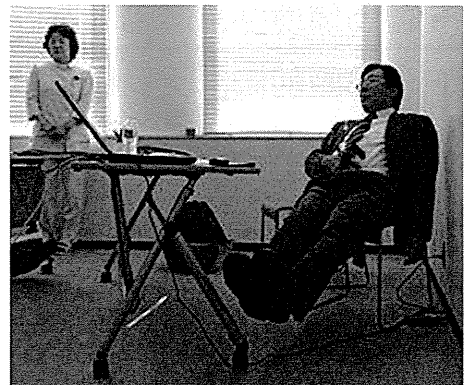


図3 休日の疲労感

- H24年の「こころの健康調査」の結果（図2、図3）では、勤務日では約半数の人が「疲れている・やや疲れている」、休日でも約3分の1の人が「疲れている・やや疲れている」と回答しています。休日でもなかなか疲労がとれないことが分かりました。

## 丹田呼吸法のすすめ

- リラックス方法の一つとして、大変有効な呼吸法をご紹介します。
- 自律神経は、呼吸によってのみ意識的にコントロールできます。よくある例として、緊張した時に深呼吸すると落ち着きます。
- 東洋医学的に丹田とは『気』（元気、やる気、生命力）が貯まる場所と言われています。丹田の場所は、椅子の前に腰かけて足を投げだし、その足を上に挙げたときに腹筋が張る箇所です（おへその下あたり）。
- 軽く両手で丹田を押さえ、丹田を意識し、「いち、にい、さん〜」で鼻から息を全部吐ききります。次に、丹田を意識し、鼻から大きく息を吸い込みます。
- 丹の田場所がわかれば、足を挙げなくてもできるので、会議中、バスや電車の中、どこでも丹田呼吸を心がけて下さい。



2012.12 TL研修での一コマ

# あなたの睡眠力は？

セルフ  
チェック

●あなたが実行していることに○、していないことに×をつけて下さい。

|  |                 |
|--|-----------------|
| <ul style="list-style-type: none"> <li>• 毎朝決まった時刻に起きている ( )</li> <li>• 朝の光を30分浴びている ( )</li> <li>• 昼寝をする時は30分以内である ( )</li> </ul>  | 生活習慣<br>●リズムと光  |
| <ul style="list-style-type: none"> <li>• 規則正しい3度の食事をとっている ( )</li> </ul>   | ●食事             |
| <ul style="list-style-type: none"> <li>• 日中はよく体を動かしている ( )</li> <li>• 規則正しい運動習慣がある ( )</li> </ul>  | ●運動             |
| <ul style="list-style-type: none"> <li>• 睡眠時間にはこだわらない ( )</li> <li>• 眠くなるまで床につかない ( )</li> </ul>   | 睡眠に対する<br>考え方   |
| <ul style="list-style-type: none"> <li>• 枕や布団は、自分にあったものである ( )</li> <li>• 寝る環境は、静かで、照明が暗い ( )</li> <li>• 寝る環境は、適当な室温・湿度である ( )</li> </ul>  | 寝室の環境           |
| <ul style="list-style-type: none"> <li>• 寝る直前に、テレビ・パソコン・携帯を見ない ( )</li> <li>• 寝る直前に緊張を強いる仕事をしない ( )</li> <li>• 寝る直前の入浴はぬるめの湯（40℃前後）である ( )</li> <li>• 寝る直前は、リラックスしている ( )</li> </ul> | 寝る前の過ごし方<br>●状態 |
| <ul style="list-style-type: none"> <li>• カフェインは、夕食以降はとらない ( )</li> <li>• アルコールは、寝る直前は飲まない ( )</li> <li>• タバコは、寝る1～2時間前は吸わない ( )</li> </ul>   | ●嗜好品            |

○の数      つ

×の数      つ



## 睡眠力向上のすすめ

- 不眠で悩む人に話を聞いてみると、寝酒、コーヒーの多飲、長時間の昼寝・・・と睡眠を妨げる習慣があります。
- ○の数が多いほど、良質な睡眠をとることができますが、×の数が多かった項目があれば、以下を参考にして、自分でできそうなことを試してみてください。



### 【生活習慣】

#### ●リズムと光

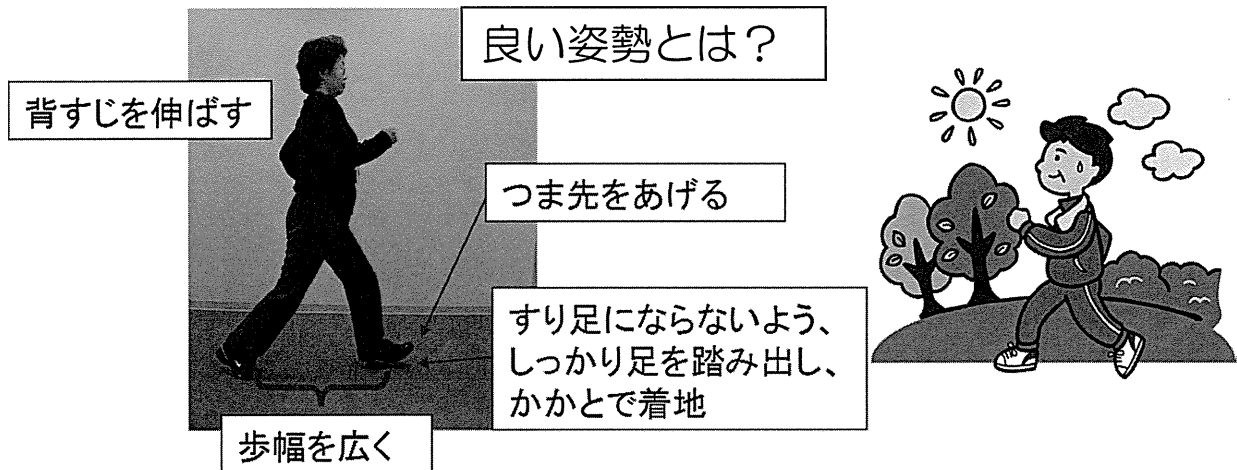
- 体のリズムは、脳と胃袋にあります。脳を刺激するために、朝6～8時の朝の光を浴びましょう。白湯やホットコーヒーで、胃袋を刺激する方法もあります。
- 休日も平日と同じ時刻に起きましょう。その分夜は早めに就寝しましょう。起きる時刻に2時間以上の差があると、夜眠れなくなり、平日の朝に起きるのが辛くなります。
- 昼寝をする場合は、15時までにとりましょう。長い昼寝はかえってぼんやりのもと。夕方以降に昼寝をすると、リズムが崩れ、身体がだるくなります。

#### ●食事

- 特に朝食は、心と身体の日覚めに重要です。

## ●運動

- 歩くことは有効な運動です。
  - ポイントは、速めのスピード・姿勢良く・20～30分間歩くことです。



- ラジオ体操も有効な運動です。
  - 起床時や昼休みなど気軽にできます。ラジオ体操第一は、一般の人が行える体操、第二は働き盛りの人が体を鍛え筋力を強化する体操です。

### 【睡眠に対する考え方】

- 睡眠時間は、長い人や短い人がいますし、季節でも変わります。昼間に支障がなければ、あまりこだわらないようにしましょう。
- 眠ろうとする意気込みで、頭がさえてしまいます。

## 【寝室の環境】

- 周囲の音が気になる時は、耳栓を試してみましょう。
- 寝る前30分から温度（夏は24～26℃、冬は12～14℃）を調節しましょう。



## 【寝る前の過ごし方】

### ●環境

- 寝る前に、テレビ・パソコン・携帯を見る、仕事をすることは、頭が冴えるのでやめましょう。
- 熱いお風呂はリラックスできないので、避けてください。
- 寝る前は、激しい運動は避けましょう。腹式呼吸、ヨガ、アロマセラピーがお勧めです。

### ●嗜好品

- カフェインは、コーヒーだけでなく、緑茶、紅茶、コーラ、栄養ドリンク、チョコレートにも含まれるので、控えましょう。
- 寝るための飲酒（寝酒）はやめましょう。寝つきは良くなりますが、その後の睡眠が浅くなり、夜間・早朝に目が覚めます。



## 長い道のりを進むために大切なこと

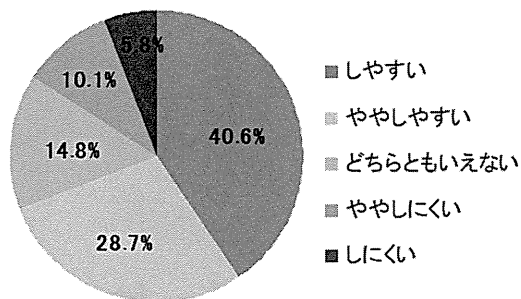


図4 休暇の取得のしやすさ

・H24年の「こころの健康調査調査」の結果（図4）では、69.3%の人が「休暇を取得しやすい・ややしやすい」と回答していました。

・一方で16.9%の人が「しにくい・ややしにくい」と回答していました。

・災害後は、「皆が大変だから、私も頑張らなくては」「もっと大変な人がいる」と思い、休むことを遠慮がちでした。しかし、復興は長期戦です。走り続けていると燃えつきてしまいます。

・長期戦では休養・リラックスが心身の健康に必要です。

・仲間同士でいたわって下さい。気持ちをためないで下さい。

・管理職は、メンバーに声をかけましょう。必要に応じて仕事の負荷を調整しましょう。また率先して休む姿をみせて下さい（メンバーが休みやすくなるためにも）。

・家族や友人の支え合いを大切にして下さい。今回の災害で、「家族との絆」を感じたという声を多くの方々からお聞きしました。休暇を取ることは、自分のためだけでなく、家族のためにもお勧めします。

# あとがき

- 本小冊子は、防衛医科大学校重村淳講師・愛媛大学谷川教授による「こころの健康調査（H23年、24年）」の結果、谷川教授による「管理職研修・TL研修」の内容などを元に、作成しました。
- 内容について、ご意見、ご質問などございましたら、以下までお問い合わせ下さい。
- 作成者  
福島第一・第二健康管理室 内線964-4181  
外線0240-25-1371  
技術開発研究所ヒューマンファクターG  
内線91-82-6408  
外線045-394-6087

# Associations between Disaster Exposures, Peritraumatic Distress, and Posttraumatic Stress Responses in Fukushima Nuclear Plant Workers following the 2011 Nuclear Accident: The Fukushima NEWS Project Study

Jun Shigemura<sup>1\*</sup>, Takeshi Tanigawa<sup>2</sup>, Daisuke Nishi<sup>3</sup>, Yutaka Matsuoka<sup>4,5</sup>, Soichiro Nomura<sup>1</sup>, Aihide Yoshino<sup>1</sup>

**1** Department of Psychiatry, National Defense Medical College, Tokorozawa, Saitama, Japan, **2** Department of Public Health, Ehime University Graduate School of Medicine, Toon, Ehime, Japan, **3** Department of Mental Health Policy and Evaluation, National Institute of Mental Health, National Center of Neurology and Psychiatry, Kodaira, Tokyo, Japan, **4** Department of Clinical Epidemiology, Translational Medical Center, National Center of Neurology and Psychiatry, Kodaira, Tokyo, Japan, **5** Department of Psychiatry, National Disaster Medical Center, Tachikawa, Tokyo, Japan

## Abstract

**Background:** The 2011 Fukushima Daiichi Nuclear Power Plant accident was the worst nuclear disaster since Chernobyl. The nearby Daini plant also experienced substantial damage but remained intact. Workers for the both plants experienced multiple stressors as disaster victims and workers, as well as the criticism from the public due to their company's post-disaster management. Little is known about the psychological pathway mechanism from nuclear disaster exposures, distress during and immediately after the event (peritraumatic distress; PD), to posttraumatic stress responses (PTSR).

**Methods:** A self-report questionnaire was administered to 1,411 plant employees (Daiichi,  $n=831$ ; Daini,  $n=580$ ) 2–3 months post-disaster (total response rate: 80.2%). The socio-demographic characteristics and disaster-related experiences were assessed as independent variables. PD and PTSR were measured by the Japanese versions of Peritraumatic Distress Inventory and the Impact of Event Scale-Revised, respectively. The analysis was conducted separately for the two groups. Bivariate regression analyses were performed to assess the relationships between independent variables, PD, and PTSR. Significant variables were subsequently entered in the multiple regression analyses to explore the pathway mechanism for development of PTSR.

**Results:** For both groups, PTSR highly associated with PD (Daiichi: adjusted  $\beta$ , 0.66;  $p<0.001$ ; vs. Daini: adjusted  $\beta$ , 0.67;  $p<0.001$ ). PTSR also associated with discrimination/slurs experience (Daiichi: 0.11;  $p<0.001$ ; vs. Daini, 0.09;  $p=0.005$ ) and presence of preexisting illness(es) (Daiichi: 0.07;  $p=0.005$ ; vs. Daini: 0.15;  $p<0.001$ ). Other disaster-related variables were likely to be associated with PD than PTSR.

**Conclusion:** Among the Fukushima nuclear plant workers, disaster exposures associated with PD. PTSR was highly affected by PD along with discrimination/slurs experience.

**Citation:** Shigemura J, Tanigawa T, Nishi D, Matsuoka Y, Nomura S, et al. (2014) Associations between Disaster Exposures, Peritraumatic Distress, and Posttraumatic Stress Responses in Fukushima Nuclear Plant Workers following the 2011 Nuclear Accident: The Fukushima NEWS Project Study. PLoS ONE 9(2): e87516. doi:10.1371/journal.pone.0087516

**Editor:** Kenji Hashimoto, Chiba University Center for Forensic Mental Health, Japan

**Received:** September 10, 2013; **Accepted:** December 22, 2013; **Published:** February 19, 2014

**Copyright:** © 2014 Shigemura et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

**Funding:** This work was partly supported by Health and Labour Sciences Research Grants (Research on Occupational Safety and Health H24-001 and 25-H24-001) from the Ministry of Health Labour and Welfare of Japan and by Core Research for Evolutional Science and Technology (CREST), Japan Science and Technology Agency. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

**Competing Interests:** JS, SN, and AY provided mental health assistance to TEPCO Fukushima Daiichi and Daini nuclear power plant employees according to official requests from Daini and a Japanese government cabinet order to the Ministry of Defense. TT is a Daini part-time occupational physician. DN and YM report no conflict of interest disclosures. This does not alter the authors' adherence to all the PLOS ONE policies on sharing data and materials.

\* E-mail: shige@ndmc.ac.jp

## Introduction

On March 11, 2011, a 9.0 magnitude earthquake and series of tsunami attacked the northeastern coast of Japan (the Great East Japan Earthquake). Tokyo Electric Company (TEPCO) Fukushima Daiichi Nuclear Power Plant (Daiichi) was heavily damaged, eventually leading to plant explosions, nuclear plant meltdowns, release of radioactive materials, and mandatory evacuation of the surrounding residents. It became the largest nuclear disaster since

the 1986 Chernobyl accident, and only the second disaster (along with Chernobyl) to measure Level 7 severity on the International Nuclear Event Scale. Recovery efforts are expected to continue for decades.

Chernobyl mental health studies [1–3] suggest that among the affected population, plant workers are at particular risk for experiencing psychological distress. The Fukushima nuclear plant workers have been working under extremely hazardous conditions

**Table 1.** Comparisons of two subject groups (Daiichi vs. Daini).

|                                     |                                  | Subject groups |      |          |      |          |      |                   |          |           |
|-------------------------------------|----------------------------------|----------------|------|----------|------|----------|------|-------------------|----------|-----------|
|                                     |                                  | Total          |      | Daiichi  |      | Daini    |      | Daiichi vs. Daini |          |           |
|                                     |                                  | <i>n</i>       | %    | <i>n</i> | %    | <i>n</i> | %    | $\chi^2$          | <i>p</i> |           |
| <b>Total</b>                        |                                  | 1,411          | 100  | 831      | 100  | 580      | 100  |                   |          |           |
| <b>Sociodemographic factors</b>     | Age, years                       | 20–29          | 381  | 25.6     | 227  | 25.7     | 154  | 25.4              |          |           |
|                                     |                                  | 30–39          | 347  | 23.3     | 202  | 22.9     | 145  | 23.9              |          |           |
|                                     |                                  | 40–49          | 395  | 26.5     | 235  | 26.6     | 160  | 26.4              |          |           |
|                                     |                                  | 50–59          | 348  | 23.4     | 211  | 23.9     | 137  | 22.6              |          |           |
|                                     |                                  | 60–69          | 18   | 1.2      | 8    | 0.9      | 10   | 1.7               | 2.09     | 0.72      |
|                                     |                                  | Sex            | Male | 1,337    | 94.8 | 804      | 96.8 | 533               | 91.9     | 15.5      |
|                                     | Supervisory work status          | Yes            | 147  | 10.4     | 86   | 10.3     | 61   | 10.5              | 0.07     | 0.79      |
|                                     | Preexisting illness(es)          | Yes            | 203  | 14.4     | 126  | 15.2     | 77   | 13.3              | 0.96     | 0.33      |
| <b>Disaster-related experiences</b> | Discrimination/slurs             | Yes            | 179  | 12.7     | 115  | 13.8     | 64   | 11                | 2.97     | 0.085     |
|                                     | Near-death experience            | Yes            | 593  | 42       | 446  | 53.7     | 147  | 25.3              | 117      | <0.001*** |
|                                     | Escape from tsunami              | Yes            | 175  | 12.4     | 82   | 9.9      | 93   | 16                | 12.9     | <0.001*** |
|                                     | Witnessing of plant explosion(s) | Yes            | 372  | 26.4     | 303  | 36.5     | 69   | 11.9              | 112      | <0.001*** |
|                                     | Family member death(s)           | Yes            | 81   | 5.7      | 50   | 6        | 31   | 5.3               | 0.11     | 0.74      |
|                                     | Colleague death(s)               | Yes            | 249  | 17.6     | 166  | 20       | 83   | 14.3              | 7.49     | 0.006**   |
|                                     | Major property loss              | Yes            | 408  | 28.9     | 269  | 32.4     | 139  | 24                | 11.1     | 0.001**   |
|                                     | Home evacuation                  | Yes            | 945  | 67       | 582  | 70       | 363  | 62.6              | 8.2      | 0.004**   |

\*\**p*<0.01.

\*\*\**p*<0.001.

doi:10.1371/journal.pone.0087516.t001

[4], and a majority of the workers have been under a multitude of stressors. In addition to workplace traumatic stress, such stressors include victim experiences, grief reactions, and the criticism from the public due to their company’s post-disaster management [5].

Responses occurring at the time of a trauma and immediately after (i.e., peritraumatic responses) include emotional changes (e.g., helplessness, guilt, horror, and fear of death) and physical reactions (e.g., sweating, shaking, and bladder/bowel responses). A meta-analysis [6] has suggested that such peritraumatic distress (PD) is one of the strongest predictors of future posttraumatic stress responses (PTSR), such as intrusion, avoidance/numbing, and hyperarousal, subsequently developing posttraumatic stress disorder (PTSD) among the affected individuals.

Our previous study [7] examined the mental health outcomes of the Fukushima Daiichi and Daini workers 2–3 months post-disaster. This report suggested their enormous and complex disaster exposures resulted in high rates of general psychological distress and PTSR. As of the writing of this article, little is known about the psychological pathway mechanism from multiple nuclear disaster exposures, PD, to PTSR among the affected people. In order to explore this development pathway of PTSR, we conducted a cross-sectional study to explore this association among Fukushima nuclear plant workers post-accident.

**Methods**

Following approvals from the Ethics Committees of Ehime University and National Defense Medical College, full-time TEPCO employees of Fukushima Daiichi and the nearby Daini nuclear power plants (Daiichi: *n* = 1,053; Daini: *n* = 707) were invited to participate in the present study, 2–3 months post-disaster (May–June, 2011). Daini is located 12 km south of

Daiichi, had suffered tsunami attacks, and was close to nuclear meltdown. None of the workers had reported acute radiation exposure symptoms. Written consent was obtained from subjects upon enrollment in the study.

We gathered information about respondents’ socio-demographic information, disaster-related stressors, and the extent of PD using a self-report questionnaire. Disaster-related stressors were determined based on our initial on-site services [5] and dichotomously coded as “yes” or “no.” We asked subjects whether they had experienced discrimination/slurs (*sabetsu/chuushou* in Japanese) because TEPCO workers were under public criticism. Our studies revealed that PTSR in workers were complex and linked to their multiple disaster experiences, including work-related trauma, disaster victim distress, grief experience, and discrimination from the public [5,7]. We assessed colleague death(s) as a potential stressor because two young Daiichi employees and a Daini contractor had died due to tsunami.

PD was measured using a Japanese version of the Peritraumatic Distress Inventory (PDI) [8,9]. The PDI is a 13-item scale quantifying fear and sense of helplessness in the period during and immediately after a traumatic experience. The response format was a five-point Likert scale ranging from 0 to 4; the total score ranged from 0 to 52, and higher scores represent higher PD. A study among motor vehicle accident survivors showed a PDI cutoff score of 22/23 to predict PTSD [10]. The scale’s internal consistency is high (Cronbach’s alpha = 0.86).

PTSR was quantified using a Japanese version of the Impact of Event Scale-Revised (IES-R) [11]. This is a 22-item scale measuring PTSR domains of intrusion, avoidance/numbing, and hyperarousal. The detailed explanation is available on our previous paper [7].

**Table 2.** Bivariate and multivariate relationships: peritraumatic stress and independent variables.

|                                     |   | Associations with PDI |       |         |       |                       |       |         |       |                    |       |         |       |                       |       |         |       |           |
|-------------------------------------|---|-----------------------|-------|---------|-------|-----------------------|-------|---------|-------|--------------------|-------|---------|-------|-----------------------|-------|---------|-------|-----------|
|                                     |   | Daiichi (n=831)       |       |         |       |                       |       |         |       | Daini (n=580)      |       |         |       |                       |       |         |       |           |
|                                     |   | Bivariate analysis    |       |         |       | Multivariate analysis |       |         |       | Bivariate analysis |       |         |       | Multivariate analysis |       |         |       |           |
|                                     |   | B                     | SE    | $\beta$ | p     | B                     | SE    | $\beta$ | p     | B                  | SE    | $\beta$ | p     | B                     | SE    | $\beta$ | p     |           |
| <b>Sociodemographic factors</b>     | <b>Age</b>                              | Years                 | -0.08 | 0.03    | -0.10 | 0.004**               | -0.04 | 0.03    | -0.04 | 0.24               | -0.06 | 0.03    | -0.07 | 0.077                 |       |         |       |           |
|                                     | <b>Sex</b>                              | Male                  | 2.93  | 1.83    | 0.06  | 0.11                  |       |         |       |                    | 3.32  | 1.31    | 0.11  | 0.012*                | 2.96  | 1.19    | 0.09  | 0.013*    |
|                                     | <b>Supervisory work status</b>          | Yes                   | -3.16 | 1.06    | -0.10 | 0.003**               | -1.76 | 1.01    | -0.06 | 0.08               | -3.56 | 1.16    | -0.13 | 0.002**               | -2.73 | 1.06    | -0.10 | 0.010*    |
|                                     | <b>Preexisting illness(es)</b>          | Yes                   | 0.23  | 0.91    | 0.01  | 0.80                  |       |         |       |                    | 2.02  | 1.06    | 0.08  | 0.056                 |       |         |       |           |
| <b>Disaster-related experiences</b> | <b>Discrimination/slurs</b>             | Yes                   | 5.58  | 0.92    | 0.21  | <0.001***             | 3.61  | 0.84    | 0.13  | <0.001***          | 6.59  | 1.11    | 0.24  | <0.001***             | 4.38  | 1.05    | 0.16  | <0.001*** |
|                                     | <b>Near-death experience</b>            | Yes                   | 7.35  | 0.60    | 0.39  | <0.001***             | 5.62  | 0.61    | 0.30  | <0.001***          | 6.45  | 0.78    | 0.33  | <0.001***             | 4.33  | 0.80    | 0.22  | <0.001*** |
|                                     | <b>Escape from tsunami</b>              | Yes                   | 5.92  | 1.07    | 0.19  | <0.001***             | 2.19  | 1.00    | 0.07  | 0.028*             | 5.36  | 0.95    | 0.23  | <0.001***             | 2.98  | 0.93    | 0.13  | 0.001**   |
|                                     | <b>Witnessing of plant explosion(s)</b> | Yes                   | 4.79  | 0.65    | 0.25  | <0.001***             | 2.53  | 0.63    | 0.13  | <0.001***          | 4.29  | 1.10    | 0.16  | <0.001***             | 2.48  | 1.01    | 0.09  | 0.015*    |
|                                     | <b>Family member death(s)</b>           | Yes                   | 1.15  | 1.36    | 0.03  | 0.40                  |       |         |       |                    | 1.07  | 1.60    | 0.03  | 0.50                  |       |         |       |           |
|                                     | <b>Colleague death(s)</b>               | Yes                   | 3.93  | 0.80    | 0.17  | <0.001***             | 1.67  | 0.78    | 0.07  | 0.033*             | 1.83  | 1.02    | 0.07  | 0.074                 |       |         |       |           |
|                                     | <b>Major property loss</b>              | Yes                   | 3.86  | 0.68    | 0.19  | <0.001***             | 2.30  | 0.63    | 0.12  | <0.001***          | 4.56  | 0.82    | 0.23  | <0.001***             | 2.87  | 0.77    | 0.14  | <0.001*** |
|                                     | <b>Home evacuation</b>                  | Yes                   | 1.97  | 0.71    | 0.10  | 0.005**               | 1.20  | 0.64    | 0.06  | 0.059              | 1.38  | 0.74    | 0.08  | 0.062                 |       |         |       |           |

\*p&lt;0.05.

\*\*p&lt;0.01.

\*\*\*p&lt;0.001.

doi:10.1371/journal.pone.0087516.t002



**Table 3.** PDI scores, confirmatory factor analysis of PDI items, and associations with IES-R.

|                        |  | Total (n= 1,411)             | Daiichi (n= 831) |      |                         |      |         |      | Daini (n= 580) |      |                         |      |         |      |
|------------------------|--|------------------------------|------------------|------|-------------------------|------|---------|------|----------------|------|-------------------------|------|---------|------|
|                        |  | Factor analysis <sup>†</sup> | Score            |      | Associations with IES-R |      |         |      | Score          |      | Associations with IES-R |      |         |      |
|                        |  |                              | Mean             | SD   | B                       | SE   | β       | t    | Mean           | SD   | B                       | SE   | β       | t    |
| <b>PDI total score</b> |  |                              | 19.46            | 9.35 | 1.13                    | 0.05 | 0.66*** | 24.9 | 15.89          | 8.64 | 1.13                    | 0.05 | 0.67*** | 21.5 |
| <b>PDI items</b>       | 1. I felt helpless to do more  | 0.69                         | 1.51             | 1.24 | 5.79                    | 0.39 | 0.46*** | 14.7 | 1.20           | 1.17 | 6.57                    | 0.43 | 0.54*** | 15.2 |
|                        | 2. I felt sadness and grief  | 0.75                         | 2.06             | 1.29 | 5.94                    | 0.38 | 0.48*** | 15.8 | 1.81           | 1.29 | 5.43                    | 0.41 | 0.48*** | 13.3 |
|                        | 3. I felt frustrated or angry I could not do more                      | 0.65                         | 1.77             | 1.30 | 5.12                    | 0.38 | 0.42*** | 13.3 | 1.48           | 1.31 | 4.50                    | 0.42 | 0.41*** | 10.8 |
|                        | 4. I felt afraid for my safety   | 0.72                         | 1.94             | 1.35 | 4.68                    | 0.38 | 0.40*** | 12.4 | 1.39           | 1.23 | 4.63                    | 0.45 | 0.40*** | 10.4 |
|                        | 5. I felt guilt that more was not done                                 | 0.62                         | 1.37             | 1.24 | 5.08                    | 0.41 | 0.40*** | 12.4 | 1.04           | 1.18 | 5.92                    | 0.44 | 0.49*** | 13.4 |
|                        | 6. I felt ashamed of my emotional reactions                            | 0.60                         | 0.70             | 0.96 | 7.70                    | 0.51 | 0.47*** | 15.1 | 0.57           | 0.86 | 7.32                    | 0.63 | 0.44*** | 11.7 |
|                        | 7. I felt worried about the safety of others                           | 0.44                         | 3.21             | 1.04 | 3.70                    | 0.53 | 0.24*** | 7.00 | 3.10           | 1.05 | 2.36                    | 0.56 | 0.18*** | 4.25 |
|                        | 8. I had the feeling I was about to lose control of my emotions        | 0.68                         | 0.91             | 1.15 | 7.07                    | 0.41 | 0.52*** | 17.3 | 0.82           | 1.09 | 6.42                    | 0.48 | 0.49*** | 13.4 |
|                        | 9. I had difficulty controlling my bowel and bladder                   | 0.34                         | 0.09             | 0.43 | 10.2                    | 1.23 | 0.28*** | 8.26 | 0.07           | 0.33 | 14.0                    | 1.71 | 0.32*** | 8.19 |
|                        | 10. I was horrified by what happened                                   | 0.64                         | 2.69             | 1.30 | 4.74                    | 0.40 | 0.39*** | 12.0 | 2.51           | 1.32 | 3.46                    | 0.43 | 0.32*** | 8.08 |
|                        | 11. I had physical reactions like sweating, shaking and pounding heart | 0.67                         | 1.06             | 1.27 | 6.21                    | 0.38 | 0.50*** | 16.5 | 0.79           | 1.11 | 7.26                    | 0.45 | 0.56*** | 16.2 |
|                        | 12. I felt I might pass out  | 0.46                         | 0.28             | 0.79 | 7.26                    | 0.65 | 0.37*** | 11.2 | 0.17           | 0.54 | 10.39                   | 1.00 | 0.40*** | 10.4 |
|                        | 13. I felt I might die   | 0.64                         | 1.84             | 1.55 | 3.82                    | 0.33 | 0.38*** | 11.6 | 0.91           | 1.26 | 3.85                    | 0.45 | 0.34*** | 8.60 |

\*\*\*p&lt;0.001.

<sup>†</sup>One-factor solution accounted for 38.3% of the total variance.

doi:10.1371/journal.pone.0087516.t003

**Table 4.** Associations between posttraumatic stress responses (IES-R) and independent variables: bivariate and multiple regression analyses.

| Associations with IES-R             |       |         |       |                     |       |         |       |                      |       |         |       |                     |       |         |       |
|-------------------------------------|-------|---------|-------|---------------------|-------|---------|-------|----------------------|-------|---------|-------|---------------------|-------|---------|-------|
| Daiichi (n=831)                     |       |         |       |                     |       |         |       |                      |       |         |       |                     |       |         |       |
| Daini (n=580)                       |       |         |       |                     |       |         |       |                      |       |         |       |                     |       |         |       |
| Bivariate regression                |       |         |       | Multiple regression |       |         |       | Bivariate regression |       |         |       | Multiple regression |       |         |       |
| B                                   | SE    | $\beta$ | p     | B                   | SE    | $\beta$ | p     | B                    | SE    | $\beta$ | p     | B                   | SE    | $\beta$ | p     |
| <b>Sociodemographic factors</b>     |       |         |       |                     |       |         |       |                      |       |         |       |                     |       |         |       |
| Age, years                          | 0.02  | 0.05    | 0.02  | 0.68                |       |         |       |                      | 0.07  | 0.05    | 0.06  | 0.19                |       |         |       |
| Sex                                 | 4.93  | 2.98    | 0.06  | 0.10                |       |         |       |                      | 6.56  | 2.12    | 0.13  | 0.002**             | 2.22  | 1.63    | 0.04  |
| Supervisory work status             | -1.26 | 1.86    | -0.02 | 0.50                |       |         |       |                      | -1.08 | 1.95    | -0.02 | 0.580               |       |         |       |
| Preexisting illness(es)             | 3.78  | 1.53    | 0.09  | 0.014*              | 3.23  | 1.16    | 0.07  | 0.005**              | 7.78  | 1.73    | 0.18  | <0.001***           | 6.60  | 1.33    | 0.15  |
| <b>Disaster-related experiences</b> |       |         |       |                     |       |         |       |                      |       |         |       |                     |       |         |       |
| Discrimination/slurs                | 10.5  | 1.53    | 0.23  | <0.001***           | 5.03  | 1.23    | 0.11  | <0.001***            | 10.6  | 1.85    | 0.23  | <0.001***           | 4.11  | 1.46    | 0.09  |
| Near-death experience               | 6.34  | 1.07    | 0.20  | <0.001***           | -2.74 | 0.93    | -0.09 | 0.003**              | 7.38  | 1.33    | 0.22  | <0.001***           | -1.31 | 1.12    | -0.04 |
| Escape from tsunami                 | 7.61  | 1.78    | 0.15  | <0.001***           | 2.20  | 1.42    | 0.04  | 0.12                 | 8.23  | 1.58    | 0.21  | <0.001***           | 2.59  | 1.28    | 0.07  |
| Witnessing of plant explosion(s)    | 4.31  | 1.12    | 0.13  | <0.001***           | -0.85 | 0.91    | -0.03 | 0.35                 | 3.43  | 1.83    | 0.08  | 0.062               |       |         |       |
| Family member death(s)              | 3.44  | 2.32    | 0.05  | 0.14                |       |         |       |                      | 2.13  | 2.61    | 0.03  | 0.41                |       |         |       |
| Colleague death(s)                  | 4.50  | 1.37    | 0.11  | 0.001**             | 0.85  | 1.07    | 0.02  | 0.43                 | -0.05 | 1.70    | 0     | 0.98                |       |         |       |
| Major property loss                 | 5.66  | 1.16    | 0.17  | <0.001***           | 1.00  | 0.92    | 0.03  | 0.28                 | 6.48  | 1.36    | 0.19  | <0.001***           |       |         |       |
| Home evacuation                     | 3.50  | 1.18    | 0.10  | 0.003**             | 0.87  | 0.91    | 0.03  | 0.34                 | 2.09  | 1.22    | 0.07  | 0.09                | 0.23  | 0.92    | 0.01  |
| <b>PDI total score</b>              | 1.13  | 0.05    | 0.66  | <0.001***           | 1.12  | 0.05    | 0.66  | <0.001***            | 1.13  | 0.05    | 0.67  | <0.001***           | 1.06  | 0.06    | 0.63  |

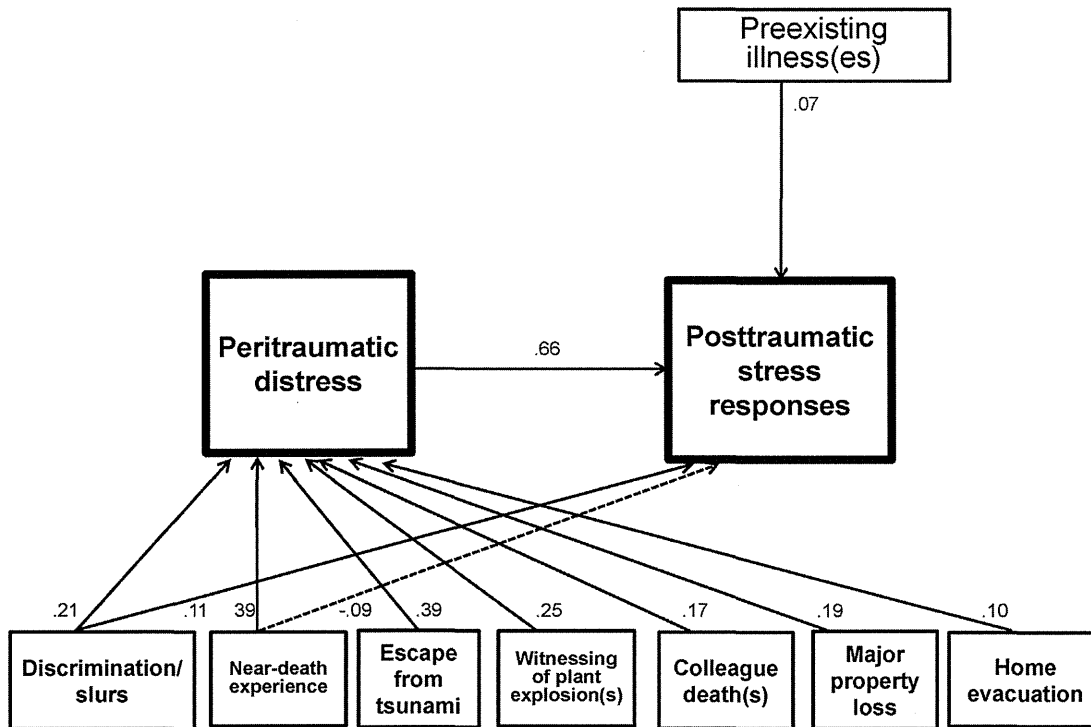
\*p<0.05.

\*\*p<0.01.

\*\*\*p<0.001.

doi:10.1371/journal.pone.0087516.t004

Daiichi group



**Figure 1. Path model for the posttraumatic stress responses of the Daiichi group.** All paths have significance of  $p < 0.05$ . A dotted arrow shows a negative correlation. PD serves as an intermediary variable between various disaster exposures and PTRS. Discrimination/slurs experience was related to both PD and PTRS, whereas presence of preexisting illness(es) associated solely with PTRS. doi:10.1371/journal.pone.0087516.g001

Among those recruited, 1,495 individuals (Daiichi:  $n = 885$ , Daini:  $n = 610$ ) participated. PDI scores were missing for 84 subjects; thus, a total of 1,411 subjects (Daiichi,  $n = 831$ ; Daini,  $n = 580$ ) were enrolled in the final analysis (response rate: total, 80.2%; Daiichi, 78.9%; Daini, 82.0%).

IBM SPSS Statistics version 22 (IBM Japan, Tokyo, Japan) was used for the statistical analysis. Significance level was set at  $p < 0.05$  (two-tailed). At the beginning of the analysis, we used chi-square tests to compare differences in subject characteristics between the Daiichi and Daini subgroups. As their features were considerably different, we performed further processes separately for the two groups.

Secondly, we investigated the relationships between independent variables and PD using bivariate regression analysis. In this process and hereafter, categorical variables were handled as continuous variables, ranging from 0 to 1. Significant independent variables were considered potential PDI factors, and they were subsequently entered in the multiple regression analyses.

Thirdly, we examined the relations between PD and PTRS. According to preceding studies [8,9], we first held a confirmatory factor analysis among the 13 PDI items in order to explore whether or not each item was relevant to IES-R. We subsequently performed bivariate regression analysis to observe the associations between PDI (total score as well as 13 items) and IES-R.

Lastly, we tested the associations between PTRS and independent variables as well as PD. Similar to the previous analyses, we first conducted a bivariate regression analysis, and subsequently multiple regression analysis. Following these calculations, we created pathway maps to test our conceptual model of how independent variables associate with PD and/or PTRS.

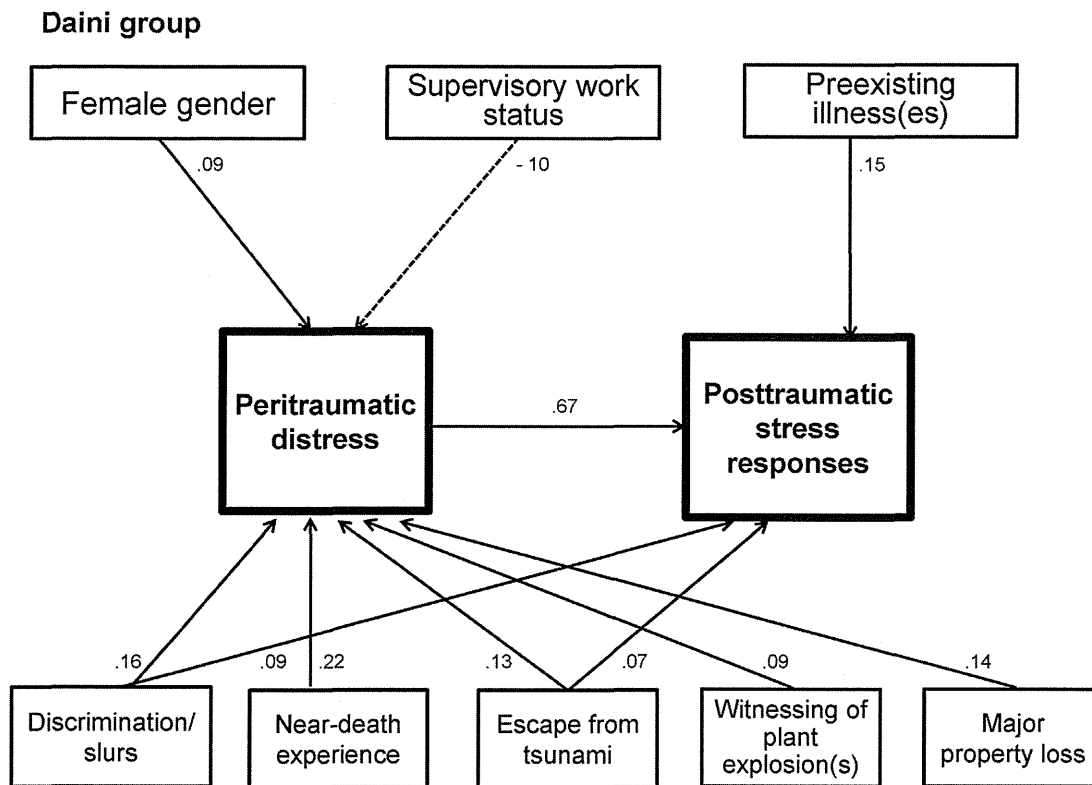
**Results**

Table 1 shows differences in disaster-related experiences between Daiichi and Daini subjects. Compared with Daini, Daiichi subjects had higher rates of disaster-related experience, except in the areas of discrimination/slurs and family member death(s) experience.

Table 2 shows the relations between independent variables and PDI. For both groups, PDI associated with multiple disaster exposures (discrimination/slurs, near-death experience, escape from tsunami, witnessing of plant explosion[s], and major property loss). For Daiichi, PDI was related to colleague death(s) experience for Daiichi; female gender, non-supervisory work status, and presence of preexisting illness(es) for Daini.

Table 3 shows the relations between PD and PTRS. The PDI total score, along with all of the 13 PDI items, associated with IES-R for both groups ( $p < 0.001$ ). According to the confirmatory factor analysis, one-factor solution accounted for 38.3% of the total variance. Standardized coefficients of the items were all  $> 0.44$ , except that of item 9, which was 0.34.

Table 4 shows the bivariate and multivariate relations between PTRS and independent variables as well as PDI. For both groups, PTRS highly associated with PD (Daiichi: adjusted  $\beta$ , 0.66;  $p < 0.001$ ; vs. Daini: adjusted  $\beta$ , 0.67;  $p < 0.001$ ). PTRS also associated with discrimination/slurs experience (Daiichi: adjusted  $\beta$ , 0.11;  $p < 0.001$ ; vs. Daini, adjusted  $\beta$ , 0.09;  $p = 0.005$ ) and presence of preexisting illness(es) (Daiichi: adjusted  $\beta$ , 0.07;  $p = 0.005$ ; vs. Daini: adjusted  $\beta$ , 0.15;  $p < 0.0001$ ). For Daiichi, PTRS negatively correlated with near-death experience (adjusted  $\beta$ ,  $-0.09$ ;  $p = 0.003$ ); for this variable, Variance Inflation Factor



**Figure 2. Path model for the posttraumatic stress responses of the Daini group.** All paths have significance of  $p < 0.05$ . A dotted arrow shows a negative correlation. PDI serves as an intermediary variable between various disaster exposures and PTSD. Discrimination/slurs experience was related to both PD and PTSD. Female gender was a risk factor for PD, whereas supervisory work status was a proactive factor. Presence of preexisting illness(es) associated with PTSD but not PD. doi:10.1371/journal.pone.0087516.g002

(VIF) was 1.26, and regarding other variables, VIF ranged from 1.01 to 1.31. For Daini, PTSD associated with tsunami escape experience (adjusted  $\beta$ , 0.07;  $p = 0.044$ ). VIF ranged from 1.02 to 1.25.

Figures 1 and 2 represent the psychological pathway models for the Daiichi and Daini groups, respectively. They show the mechanisms on how socio-demographic factors and various disaster exposures associate with PD and/or PTSD.

### Discussion

To our knowledge, this is the first large-scale study to examine the relationships between disaster-related exposures, PD, and PTSD following a severe nuclear disaster. Overall, Daiichi workers had higher disaster exposures than the Daini workers, and their mechanism path was complex. Our previous study [7] preliminarily reported that discrimination/slurs experience was associated with PTSD for both Daiichi and Daini groups. This paper showed further relationships of discrimination experiences and not only PTSD but also PD. First, this highlights the high impact and complexity of workers' traumatic experiences in this earthquake/tsunami/nuclear disaster. Natural disasters are generally perceived as beyond human control, whereas people tend to believe technology can be controlled, and entrust specific social organizations to do so. Thus, technological disasters have an identifiable responsible party, providing a focus for blame and compensation as well as anger, frustration, fear, and hostility [12]. Given the subjects' public role, criticisms from the very people they had been trying to protect might have an extreme impact on their

peritraumatic/posttraumatic mental health. Media communication strategies might be useful for mitigating public responses [13,14] and follow-up studies will be essential to elucidate these topics.

For both subject groups, various disaster-related exposures associated with higher PD. Our result is consistent with studies of PD among motor vehicle accident survivors [8,15], although we need to be cautious about this interpretation due to differences in the nature of the traumatic events. For Daini subjects, non-supervisory work status was associated with high PD, suggesting that a sense of control is an important modulator of risk for posttraumatic outcomes [16]. There was also a relation between PTSD and item 7 of PDI ('I felt worried about the safety of others'); this trend may be due to their organizational role during the accident. It might be helpful for job supervisors to consider vulnerabilities of workers in non-supervisory positions and emphasize safety issues during recovery efforts.

In our data, PD was a major predictive factor of PTSD. PDI was originally developed by Brunet and colleagues [9] to explore the A2 criterion of PTSD in DSM-IV [17], although there has been discussions on whether or not to utilize it for diagnostic reasons [18], and this criterion was not used as a diagnostic criterion for the DSM5, the revised diagnostic manual [19]. Nonetheless, our results show a strong relation between PD and PTSD, and further studies are essential to better understand these concerns.

It has been demonstrated that women have higher rates of PTSD than men [20]. In this study, we found an association between sex and PD in Daini but not Daiichi. In our sample, over