Assessment of Parkinson's Disease symptoms and toxin exposures in firefighters: a cross-sectional survey

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Research Article

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Abstract

BACKGROUND: Parkinson's disease (PD) has been correlated with several environmental and toxic exposures. The frequency of PD in firefighters is higher than the general population, which may be due to the high amounts of toxin exposures firefighters experience on the job. There is a need to further address the high rates of PD among this subgroup. The purpose of this study is to improve our understanding of the relationship between toxin exposure in firefighters and Parkinson's Disease symptoms.

METHODS: An anonymous survey distributed to Massachusetts firefighters assessed risk factors for toxin exposure and presence of PD symptoms. Risk factors included frequency and duration of time spent firefighting, number of fires worked, and history of toxin exposure (i.e., pesticides). We collected the frequency of PD symptoms including tremors, muscle stiffness, REM behavior disorder, hyposmia, micrographia, and decreased walking pace. Analyses comparing toxin exposure and presence of PD symptoms were performed using Chi-square testing, $p < 0.05$ was considered significant.

RESULTS: Two hundred participants were included in the study. The number of years as a firefighter, the number of days per week working, and the number of fires worked correlated with higher reports of hyposmia, micrographia, and decreased walking pace.

CONCLUSION: Firefighters have an increased risk for PD symptoms as a result of the toxin exposures that are frequently present in fires.

Background

In 1986, a fire lasting five days broke out in a junkyard in Spencer, MA, burning approximately seven hundred thousand to one million tires and requiring firefighters from ten different stations to control the blaze. Ultimately, five individuals, including four firefighters, who were involved in the Spencer fire developed Parkinson's Disease (PD) or parkinsonism. Firefighters with their numerous toxic exposures are hypothesized to be more likely to develop Parkinson's Disease symptoms.

Parkinson's Disease is the second most common neurodegenerative disorder in America affecting 1% of the population age 60 or over [1]. PD is characterized by tremors, rigidity, bradykinesia, and gait disturbances. Non-motor symptoms such as hyposmia, micrographia, and REM behavior disorder may precede PD [2]. These non-motor symptoms are not specific to PD, they are seen in Parkinsonism. The cause of PD has not been determined; however, researchers have identified several factors to be associated with the disease, including genetic, environmental, and toxic components. Prior studies have detailed five neurotoxic compounds associated with PD, including lead, styrene or vinyl benzene, benzopyrene, Polybrominated diphenyl ether, and carbon monoxide. The frequency of PD in firefighters is extremely high (1/30 people) compared to the general population (1/100 people over age 60), which may be due to the high amounts of toxin exposures firefighters experience [1, 3].

Firefighters experience heavy lead exposures as they encounter buildings heavily coated with lead-based paints and spotted with lead-comprised dust [4]. Lead exposure has shown to result in a two-fold increase in the risk for developing PD as it damages neurological pathways by inhibiting reuptake of Ca^{2+} and decreasing the quantity of dopamine within vesicles [4, 5]. Styrene or vinyl benzene is a crucial toxin encountered during fires and has been shown to alter dopamine receptor functioning and damage central and peripheral nervous systems [6].

Benzopyrene has been shown to decrease dopamine neurotransmitter regeneration in the nucleus accumbens and hippocampus of rats [7]. A prior study found benzopyrene on fire jackets, personal protective equipment of firefighters, as well as other tools and determined that current equipment cleaning standards do not eliminate benzopyrene contamination [8].

Polybrominated diphenyl ether (PBDE) is a neurotoxin used in flame-retardants and found in carpets, cushions, and home-insulating structures frequently handled by firefighters [9]. PBDE uses oxidative damage to inhibit dopamine transporters DAT and VMAT2 [4]. Many studies have established the correlation between carbon monoxide (CO) exposure and risk of PD [10, 11]. Firefighters frequently encounter CO as their own equipment known as self-contained breathing apparatuses (SCBAs) lead to elevated levels of CO found in compressed air [12].

Firefighters are exposed to several environmental toxins that increase their risk for PD and there is a need to further address the high rates of PD diagnosis among this subgroup. This study utilized a retrospective analysis based on a survey assessing the incidence of environmental toxin exposure as well as Parkinson's symptoms among firefighters.

Methods

An anonymous online survey was distributed to firefighters > 18 years of age between January 2020 and August 2020 to the Professional Firefighters of Massachusetts. Demographic data collected includes sex, age, race, and employment status (working, retired, volunteer, or family member of deceased firefighter). Risk factors for toxin exposure were assessed surveying frequency and duration of time spent firefighting and use of protective gear. A history of toxin exposure was evaluated including prior work as a welder, consumption of well water, duration of military service, as well as exposure to Agent Orange, pesticides, and jet fuel. The presence and frequency of Parkinson Disease symptoms was collected, including tremors, muscle stiffness, REM behavior disorder (i.e., acting out dreams, talking during sleep), hyposmia, micrographia, and decreased walking pace. Analyses comparing toxin exposure and presence of Parkinson symptoms were performed using Chi-square testing, $p < 0.05$ was considered significant. This study was approved by the St. Elizabeth institutional review committee (IRB #EX064) and participants provided written informed consent to participate in the study.

Results

Two hundred participants were included in the study. Among participants, 96% are male, 99% are Caucasian, 1% are Hispanic, 62% are still employed, 37% are retired, and 12% have a family history of Parkinson's disease (Table 1). Table 1 shows the range of ages in survey participants with 42% of participants being ages 40–50 and 30% being ages 60–70. Figure 1 shows the communities of survey participants. The majority of our survey participants live in rural and suburban communities in Massachusetts with several living outside of Massachusetts.

Table 1
Participant demographics.

Characteristics	**# of participants**
Total	200
Sex	
Male	192 (96%)
Age	
18–30	6 (3%)
30–40	28 (14%)
40–50	84 (42%)
60–70	60 (30%)
70–80	16 (8%)
Race	
Caucasian	192 (99%)
Hispanic	2 (1%)
Employment status	
Working	123 (62%)
Retired	74 (37%)
Volunteer	3 (1%)
Family history of PD	25 (12%)

Figure 2 demonstrates the frequency of common Parkinson Disease symptoms reported by all participants. 82% of survey participants reported muscle stiffness. 34% of participants reported tremors. 66% of participants reported REM behavior disorder. 36% of participants reported hyposmia. 15% of participants reported micrographia, and 38% of participants reported decreased walking pace.

Table 2 and Fig. 3 show the correlation of the number of years of being a firefighter with decreased walking pace, micrographia, and hyposmia. After 10 years of firefighting, participants were found to be 5 times more likely to have decreased walking pace. After 20 years, participants were 30 times more likely to have decreased walking pace and 5 times more likely to have micrographia. After 30 years, participants were twelve times more likely to have decreased walking pace and 5 times more likely to have hyposmia.

Table 2: PD symptoms of decreased walking pace, micrographia, and hyposmia correlated with exposures using Chi-square analysis.

Total	Decreased Walking Pace 73 (38%)			Micrographia 29 (15%)			Hyposmia 69 (36%)		
	Exposed	Not Exposed	$\chi 2$	Exposed	Not Exposed	$\chi 2$	Exposed	Not Exposed	$\chi 2$
Years firefighting									
>10 years	72 (41%)	1 (8%)	$\chi 2 = 4.90$, P-value 0.03*	28 (16%)	1 (8%)	$\chi 2 = 0.49$, P-value 0.48	63 (35%)	6 (50%)	$\chi 2 = 1.07$, P-value 0.30
>20 years	67 (52%)	6 (10%)	$\chi 2 = 29.94$, P-value <0.001*	25 (20%)	4 (7%)	$\chi 2 = 5.18$, P-value 0.02*	53 (41%)	16 (26%)	$\chi 2 = 3.8$, P-value 0.05
>30 years	41 (53%)	32 (28%)	$\chi 2 = 12.03$, P-value <0.001*	14 (19%)	15 (13%)	$\chi 2 = 1.00$, P-value 0.32	35 (83%)	34 (30%)	$\chi 2 = 4.87$, P-value 0.03*
>40 years	6 (60%)	67 (37%)	$\chi 2 = 2.08$, P-value 0.15	2 (20%)	27 (15%)	$\chi 2 = 0.17$, P-value 0.68	5 (50%)	64 (35%)	$\chi 2 = 0.88$, P-value= 0.35
Days/week worked									
≥ 1 day	46 (29%)	26 (84%)	$\chi 2 = 32.95$, P-value <0.001*	19 (12%)	10 (32%)	$\chi 2 = 7.96$, P-value 0.005*	54 (34%)	15 (48%)	$\chi 2 = 2.41$, P-value= 0.12
≥ 2 days	45 (29%)	27 (82%)	$\chi 2 = 32.41$, P-value <0.001*	18 (12%)	11 (33%)	$\chi 2 = 9.72$, P-value 0.002*	53 (34%)	16 (48%)	$\chi 2 = 2.64$, P-value 0.1
≥ 3 days	36 (32%)	36 (46%)	$\chi 2 = 3.66$, P-value 0.06	15 (14%)	14 (18%)	$\chi 2 = 0.61$, P-value 0.44	34 (30%)	35 (32%)	$\chi 2 = 3.9$, P-value 0.05*
≥ 4 days	33 (36%)	39 (40%)	$\chi 2 = 0.25$, P-value 0.62	14 (16%)	15 (16%)	$\chi 2 = 0.0003$, P-value is 0.99	30 (33%)	39 (39%)	$\chi 2 = 0.95$, P-value 0.33
≥ 5 days	21 (39%)	51 (38%)	$\chi 2 = 0.02$, P-value 0.89	11 (21%)	18 (13%)	$\chi 2 = 1.55$, P-value 0.21	18 (33%)	51 (38%)	$\chi 2 = 0.39$, P-value 0.53
≥ 6 days	5 (42%)	67 (38%)	$\chi 2 = 0.07$, P-value 0.79	5 (42%)	24 (14%)	$\chi 2 = 6.70$, P-value 0.01*	3 (23%)	66 (37%)	$\chi 2 = 1.03$, P-value 0.31
# of 5-9 alarm fires									
20 or more	18 (60%)	50 (33%)	$\chi 2 = 7.56$, P-value <0.05*	12 (41%)	16 (11%)	$\chi 2 = 17.19$, P-value <0.001*	13 (43%)	53 (35%)	$\chi 2 = 0.73$, P-value 0.39
40 or more	8 (67%)	60 (36%)	$\chi 2 = 4.56$, P-value 0.03*	5 (42%)	23 (14%)	$\chi 2 = 6.53$, P-value 0.01*	7 (70%)	59 (35%)	$\chi 2 = 5.14$, P-value 0.02*
100+	4 (57%)	64 (37%)	$\chi 2 = 1.16$, P-value 0.28	3 (43%)	25 (15%)	$\chi 2 = 4.04$, P-value 0.04*	4 (57%)	62 (36%)	$\chi 2 = 1.34$, P-value 0.25
Vietnam war	7 (88%)	13 (41%)	$\chi 2 = 5.63$, P-value 0.02*	3 (38%)	2 (6%)	$\chi 2 = 5.71$, P-value 0.02*	4 (50%)	11 (34%)	$\chi 2 = 0.67$, P-value 0.41
Pesticides	30 (53%)	37 (32%)	$\chi 2 = 6.71$, P-value 0.01*	17 (30%)	12 (11%)	$\chi 2 = 10.44$, P-value 0.001*	26 (45%)	39 (34%)	$\chi 2 = 1.96$, P-value 0.16

* = statistically significant value with $p < 0.05$ considered to be significant.

Table 2 and Fig. 4 show the correlation of the number of days per week working as a firefighter with decreased walking pace, micrographia, and hyposmia. Participants were thirty-three times more likely to have decreased walking pace if they had worked more than 2 days per week. Participants were eight times more likely to have micrographia if they had worked more than 1 day per week. They were ten times more likely to have micrographia if they had worked more than 2 days per week. Participants working more than 6 days per week were seven times more likely to have micrographia.

Using Chi-square analysis, Table 2 and Fig. 5 show the correlation between the number of 5–9 alarms fires worked and decreased walking pace, micrographia, and hyposmia. Fire alarms are categorized based on the severity of the fire with 5–9 fire alarms being more severe. Participants who helped with 20 or more fires were eight times more likely to have decreased walking pace and seventeen times more likely to have micrographia. Participants who have helped with 40 or more fires were five times more likely to have decreased walking pace, seven times more likely to have micrographia, and five times more likely to have hyposmia. Participants who have helped with 100 or more fires were four times more likely to have micrographia.

Table 2 and Fig. 6 show the correlation of fighting in the Vietnam War with decreased walking pace, micrographia, and hyposmia. Participants who fought in the Vietnam War were six times more likely to have decreased walking pace and six times more likely to have micrographia. Table 2 and Fig. 7 show the correlation of exposure to pesticides with decreased walking pace, micrographia, and hyposmia. Participants who have been exposed to pesticides were seven times more likely to have decreased walking pace and ten times more likely to have micrographia.

Muscle stiffness was the most commonly reported symptom occurring in 82% of our

survey responders. Several studies have discovered elevated baseline muscle pain in firefighters [13]. Dr. Park and his team found that muscle pain was the second most common reported symptom amongst firefighters likely due to heavy personal protective equipment [14]. Thus, the muscle stiffness experienced by responders may be linked to the demands of their job or early symptoms of Parkinson's Disease.

Acting out dreams was reported by 66% of survey responders. This frequency was distinctly higher than other studies which have noted REM behavior disorder in only one third of Parkinson's patients [15]. Decreased walking pace and bradykinesia were reported by 38% of respondents. Hyposmia and tremors were the fourth and fifth most reported Parkinson's symptoms at 36% and 34% respectively. Lastly, micrographia occurred in 15% of responders.

Discussion

After conducting a thorough literature search, we identified the five most common toxin exposures in fires that have been shown to increase risk for PD. Through comparative analysis, we found that the number of years firefighting, number of days per week firefighting, number of 5–9 alarm fires encountered, fighting in the Vietnam War, and exposure to pesticides all correlated with a significantly higher frequency of three Parkinsonian symptoms: micrographia, hyposmia, and decreased walking pace.

The number of years spent firefighting was broken down into 4 categories: 10 years or more, 20 years or more, 30 years or more, and 40 years or more. It is important to note that there was a small number of survey responders who had or have been firefighting for more than 40 years (n = 13). Nonetheless, the frequency of reported hyposmia and decreases in walking pace increased by an average of 5% and 7% per 10 years respectively. Meanwhile, the frequency of reported micrographia remained relatively

unchanged. The duration of a firefighter's career has also been found to positively correlate with levels of epigenetic changes, namely hypomethylation, that could lead to developments of neurodegenerative diseases [16]. Alternatively, for the number of days worked per week, the frequency of reported micrographia and walking pace increased by 6% and 3% per day, respectively.

The comparative data for the number of 5–9 alarm fires proved more difficult to gather due to the rarity of such alarm fires with only 30 being reported in Boston within the past 10 years [17]. The frequency of micrographia increased by 1% per 20 5–9 alarm fires.

Another key finding was that participation in the Vietnam War, which involved the toxin Agent Orange, was significantly correlated with decreased walking pace and micrographia. Those exposed to the Vietnam War more frequently reported decreased walking pace (88% vs. 41%), micrographia (38% vs. 6%), and hyposmia (50% vs. 34%). A number of different case studies on Vietnam War veterans have suggested that exposure to Agent Orange, specifically its 2,4-Dichlorophenoxyacetic acid component, can significantly increase the risk of Parkinson's Disease [18].

Exposure to pesticides was significantly correlated with reported frequencies of decreased walking pace (53% vs. 32%), micrographia (30% vs. 11%), and hyposmia (45% vs. 34%). These trends align with previously conducted research which has found several pesticides and herbicides that are linked to increased susceptibilities to Parkinson's Disease. For example, one study with mice models showed that exposure to the herbicides Maneb and Paraquat can lead to mutations in genes responsible for neurogenesis which can in turn impact the development of PD [19]. Additionally, one notably deleterious pesticide, rotenone, has been shown to induce oxidative damage in dopaminergic regions of several rats [20].

Although this study provides ample data to help us understand the risks associated with firefighting, there were some limitations. The advertisement for this survey stated that the study's aim was to determine the link between firefighting and Parkinson's Disease. This may have increased the response rate of those concerned about or affected by Parkinson's Disease. This study has a relatively small sample size, but the demographics appear to represent the typical firefighters in Massachusetts. The demographics of the sample were 96% being male, 99% Caucasian, and 72% being between the ages of 40 and 70.

Hyposmia was reported by 36% of study participants. It is probable that the actual frequency of hyposmia is more than what was reported as this sensory symptom can be less noticeable than motor symptoms such as bradykinesia. Hyposmia is a commonly occurring symptom of Parkinson's Disease, reported in 80% of patients [21]. It is difficult, however, to determine whether the reported hyposmia in this study was due to the progression of Parkinson's Disease or chronic exposure to fire and smoke. Research has shown that chronic smoke and toxic substance exposure can lead to irreversible hyposmia [22]. In one study, 47.5% of 102 Chicago city firefighters had significantly low scores for a sense of smell test [23].

Conclusions

The purpose of this study is to improve our understanding of the relationship between toxin exposure in firefighters and risk of Parkinson's Disease. Firefighters have an increased risk for PD symptoms as a result of the toxin exposures that are frequently present in fires. Our study showed that the number of years working as a firefighter, the number of days per week working, and the number of fires worked correlated with higher reports of Parkinson symptoms such as hyposmia, micrographia, and decreased walking pace. It is important that the scientific and firefighter community alike continue to develop studies aimed at determining the frequency of Parkinson's symptoms in firefighters as well as the specific toxin exposures that are responsible for the progression of this disease.

Declarations

Ethics approval and consent to participate

This study was approved by the St. Elizabeth institutional review committee (IRB #EX064). Participants provided written informed consent to participate in the study.

Consent for publication

The authors received written consent from Massachusetts firefighter Tim MacMillan who provided content for the background story.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to privacy policies but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

The authors have no sources of funding to declare.

Author's contributions

RK contributed to the conception and design of the survey, acquisition of the background information, data analysis and interpretation of results, and writing of the manuscript. AC contributed to the acquisition of the background information, data analysis and interpretation of the results, and writing of the manuscript. HH contributed to the acquisition of the background information, data analysis and interpretation of the results, and writing of the manuscript. OV contributed to the conception and design of the survey, acquisition of the background information, and thorough editing of the manuscript. AH

contributed to the conception and design of the survey, acquisition of the background information, and thorough editing of the manuscript. All authors read and approved the final manuscript.

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Authors' information

AH is Chair of the Department of Neurology at St. Elizabeth's Medical Center and a professor of Neurology at Tufts University School of Medicine. OV is Director of the Movement Disorder Program at St. Elizabeth's Medical Center and assistant professor of Neurology at Tufts University School of Medicine. Both AH and OV were inspired to initiate this study after noting an increased prevalence of Parkinson's Disease in their firefighting patients.

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Figures

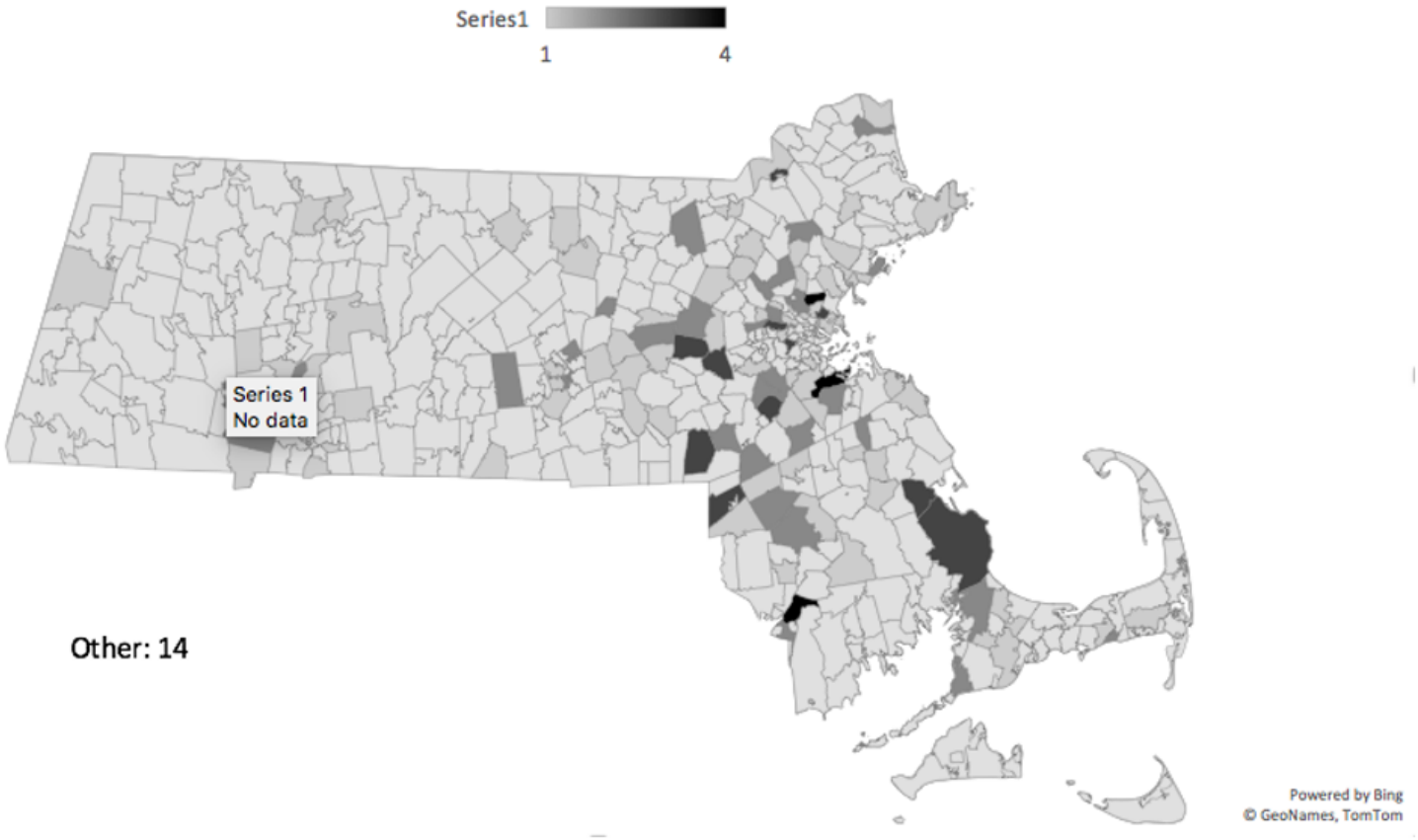

Figure 1

Zip codes of participants.

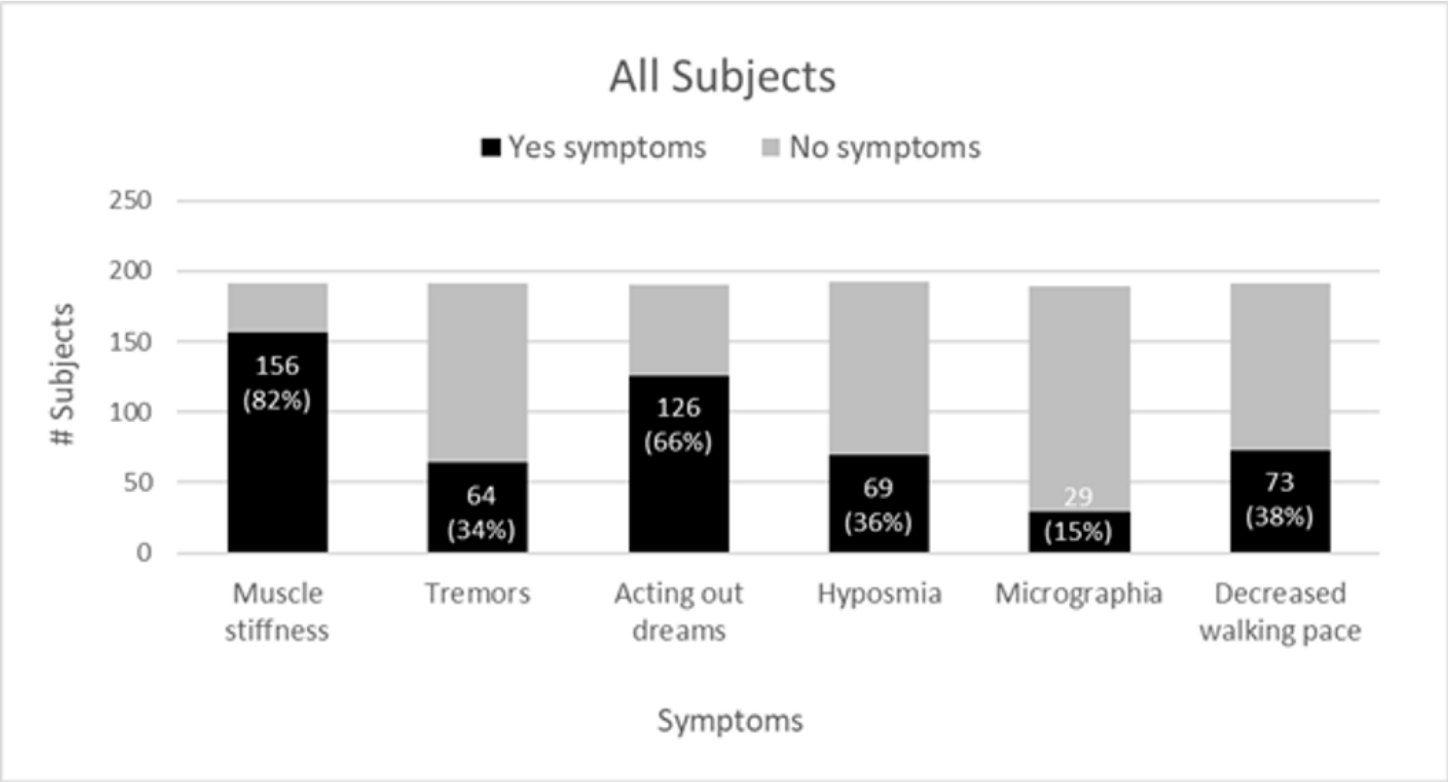

Figure 2

Frequency of common Parkinson Disease symptoms reported by all participants.

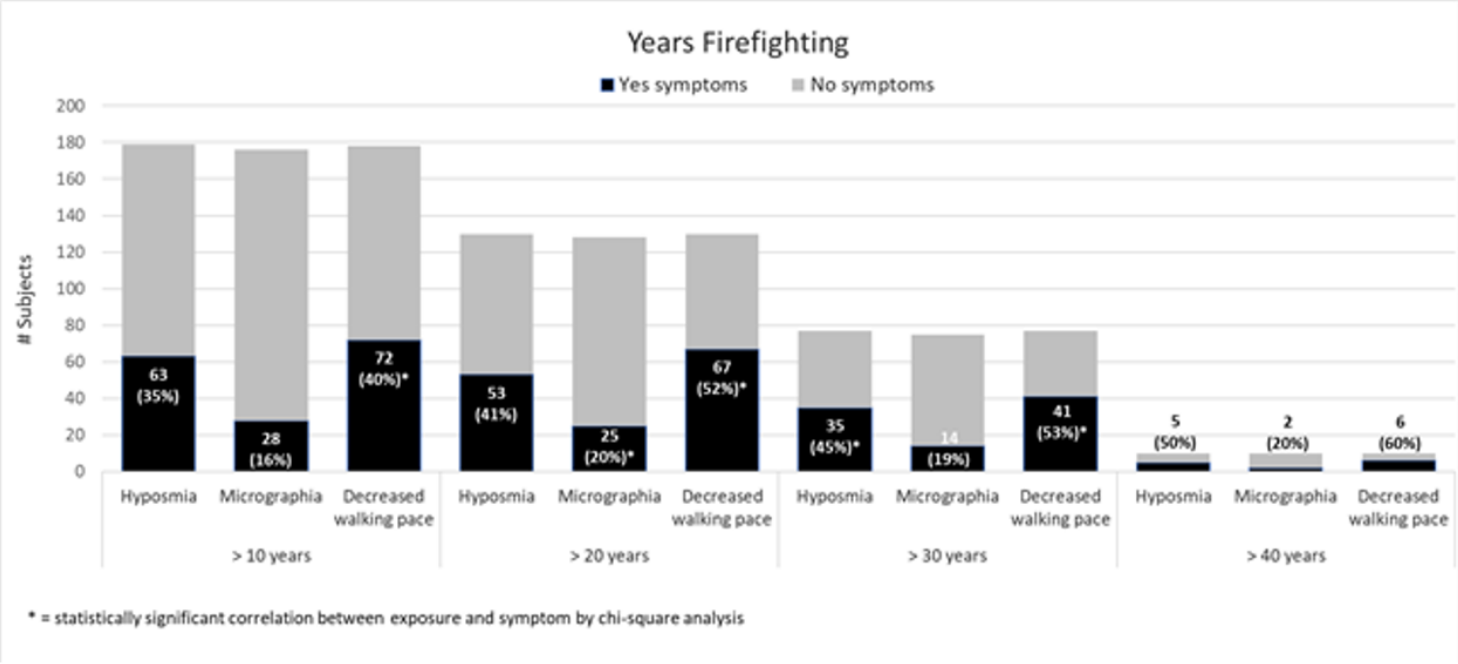

Figure 3

Number of years firefighting and reported symptoms of hyposmia, micrographia, and decreased walking pace.

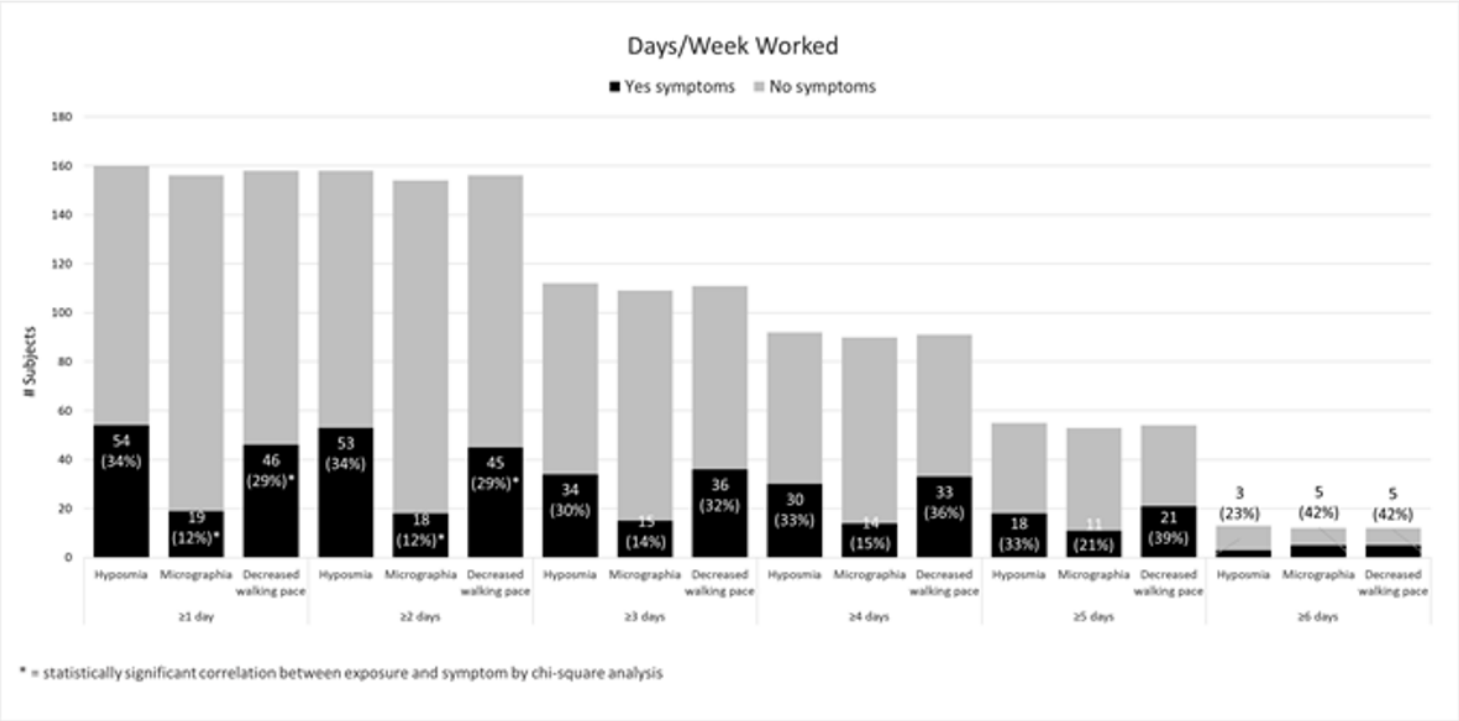

Figure 4

Number of days per week worked in the past 5 years and reported symptoms of hyposmia, micrographia, and decreased walking pace.

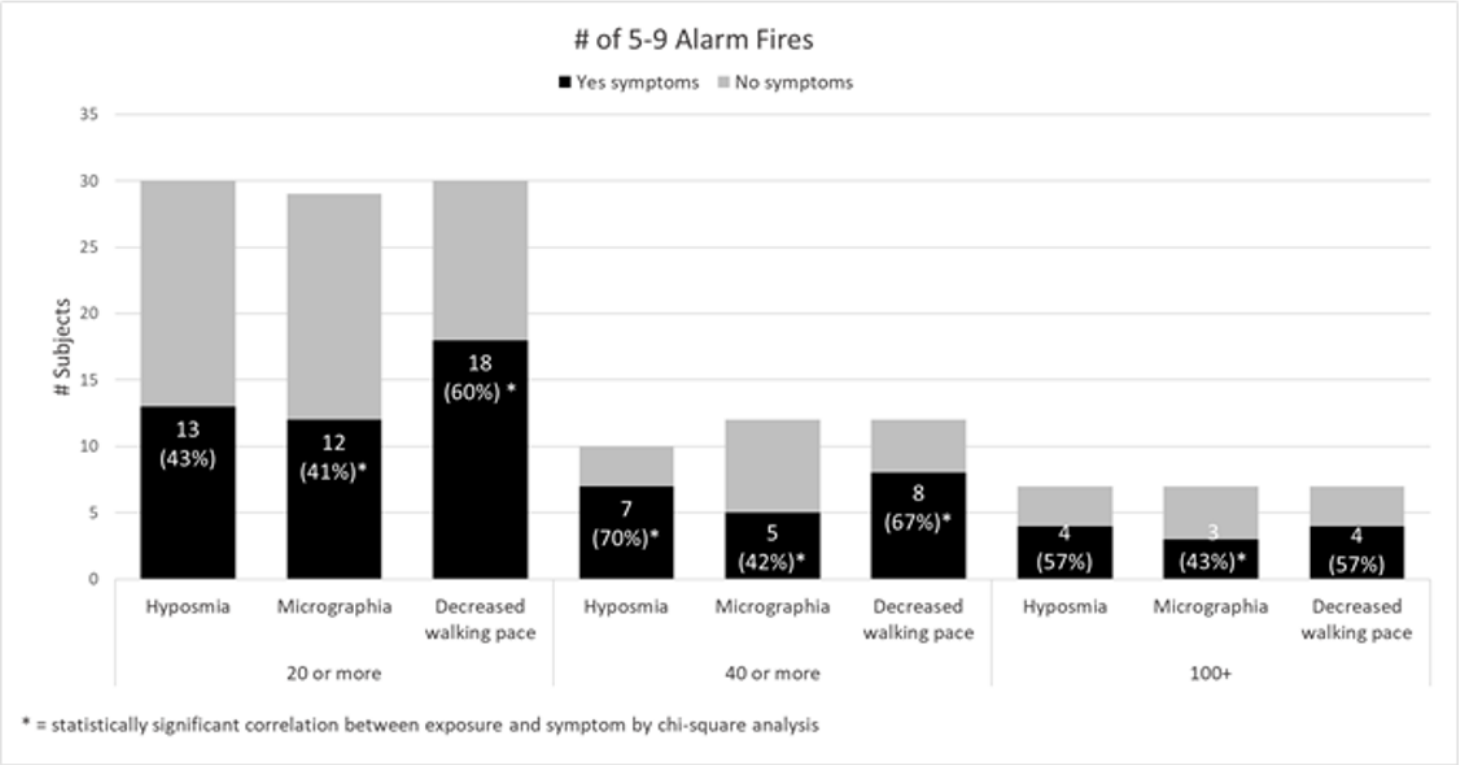

Figure 5

Number of 5-9 alarm fires helped put out and reported symptoms of hyposmia, micrographia, and decreased walking pace.

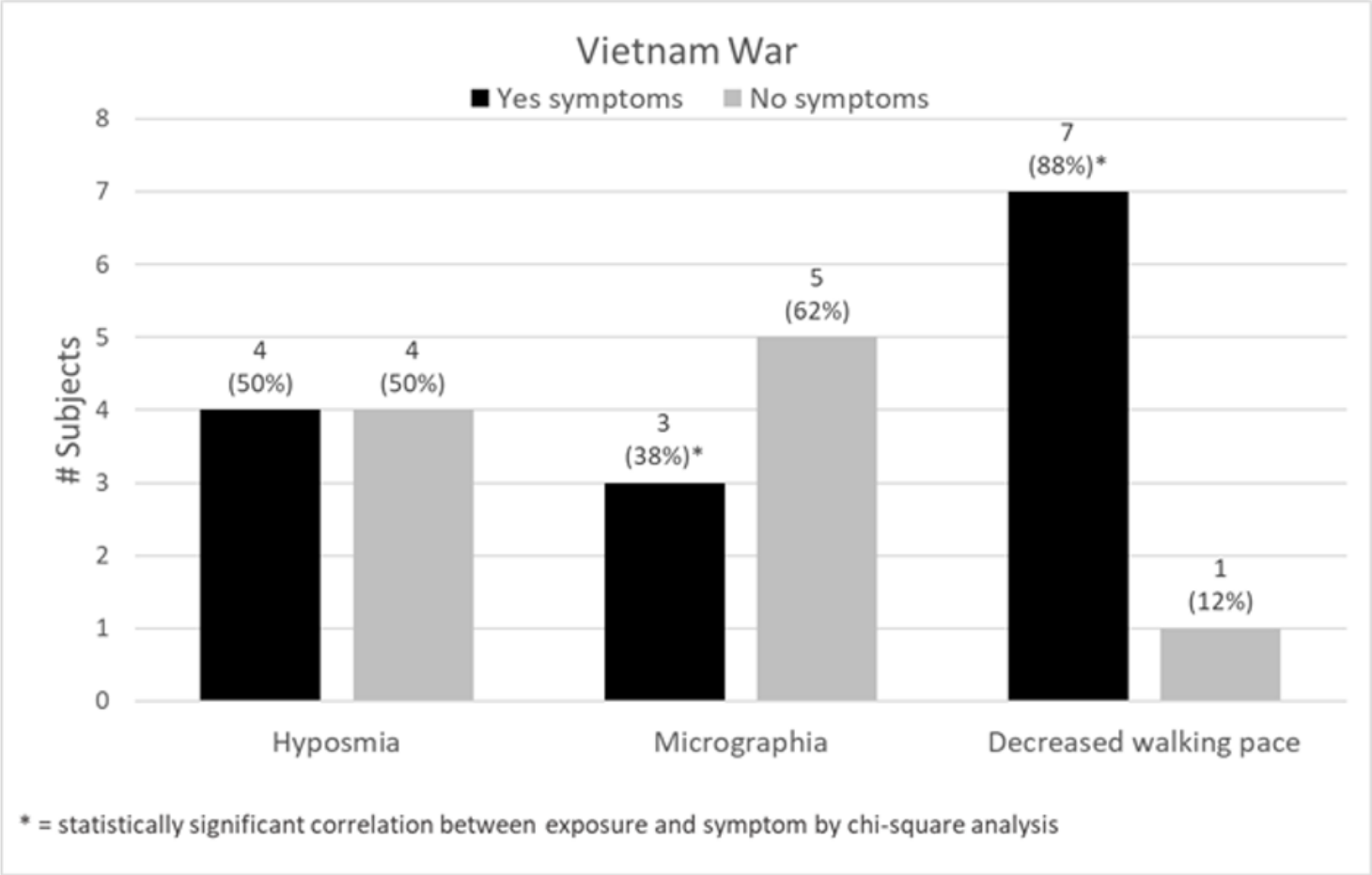

Figure 6

Symptoms reported among those who fought in the Vietnam War

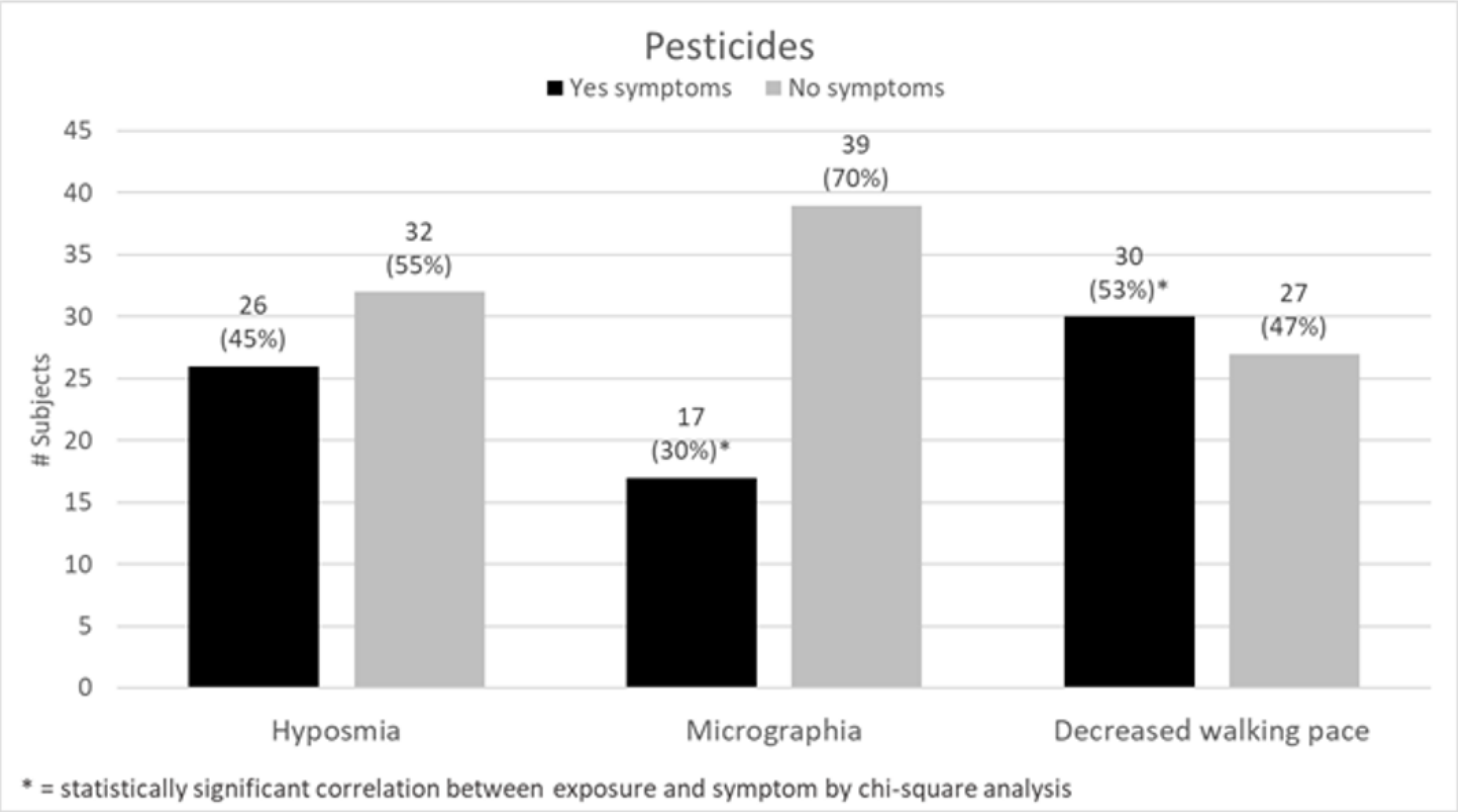

Figure 7

Symptoms reported among those exposed to pesticides.