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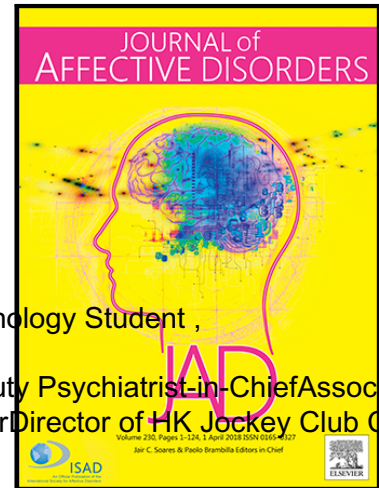
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Suicide Deaths by Gas Inhalation in Toronto: An Observational Study of Emerging Methods of Suicide



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HIGHLIGHTS

- **Gas inhalation (i.e. helium or nitrogen compressed gas, charcoal burning, or car exhaust) was the method used in 4.7% of all suicide deaths in Toronto (1998-2015), consistent with what has been observed in other countries around the world**
- **Comparing 1998-2003 to 2010-2015 there was a 1075% increase in deaths by helium (4 vs. 43 deaths) and a 533% increase in deaths by charcoal burning (3 vs. 16 deaths)**
- **13 of 14 people who died by charcoal burning whose ethnicity could be determined were of Asian background**
- **Suicide by gas inhalation is a potentially preventable cause of death and these results support increased surveillance of these deaths, efforts to restrict access to these methods, and timely interventions including minimizing media reporting of novel methods of suicide.**

ACCEPTED MANUSCRIPT

Suicide Deaths by Gas Inhalation in Toronto: An Observational Study of Emerging Methods of Suicide

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Ethical approval: This study was approved by the Sunnybrook Health Sciences Centre research ethics board (ID# 199-2012).

Author contributions:

Conception and design of the study: MS, MW, MV, AS, PY, DG.

Acquisition of study data: MS, MW, MV

Analysis and interpretation of study data: MS, MW, MV, AS, PY, DG

Wrote first draft of the paper: MS, MV

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Abstract

Background: Suicide death by gas inhalation has been the subject of global scientific interest due to a rapid increase in the use of helium and charcoal gas for suicide. These may be particularly amenable to means restriction strategies. There has been little scientific attention of this phenomenon in Canada.

Methods: A review of coroner records was conducted for all suicide deaths in Toronto (1998-2015).

Deaths were categorized as due to inhalational asphyxia by compressed gas (i.e. helium or nitrogen), charcoal burning or motor vehicle exhaust, with suicide deaths by other methods as a comparator.

Demographic, clinical and suicide specific differences between decedents in these four categories were compared using chi-squared or ANOVA global test of significance with additional pairwise comparisons where appropriate. Secular trends were also examined.

Results: Gas inhalational deaths accounted for 190 (4.7%) of all suicides in Toronto (n=4,062) over the study period and a higher proportion of males used compressed gas or motor vehicle exhaust gases than those who died by other methods (83.3% and 84.0% vs.69.7%, both $p=0.01$). Comparing 1998-2003 to 2010-2015 there was a 1075% increase in deaths by helium (4 vs. 43 deaths) and a 533% increase in deaths by charcoal burning (3 vs. 16 deaths) although helium and charcoal burning deaths still accounted for only 4.2% of total suicides 2010-2015. Deaths by helium were more likely to be accompanied by the book "Final Exit" than those by non-inhalational methods (15% vs. 0.7%, $p<0.0001$) while 13 of 14 people who died by charcoal burning whose ethnicity could be determined were Asian.

Limitations: Ethnicity and specific details of procurement of suicide methods were not systematically available in coroner records.

Discussion: Suicide by inhalational asphyxia, particularly by compressed gases, has increased substantially over time in Toronto consistent with observations in other countries. Increased

surveillance of these deaths, efforts to restrict access to these methods, and timely interventions including minimizing media reporting are all warranted.

Keywords: Suicide; Contagion; Helium; Charcoal; Motor vehicle Exhaust

Introduction

A vast body of research shows that the portrayal of suicide in the public sphere, in particular via media reporting, can have a direct impact on the pattern and observed number of suicide deaths in a region (Y.Y. Chen, F. Chen, & Yip, 2011; Etzersdorfer and Sonneck, 1998; Pirkis et al., 2009; Pirkis et al., 2006a, 2006b). One of the most notable modern examples of this social contagion phenomenon, termed the Werther Effect (Phillips, 1974), is the emergence of novel methods of inhalational asphyxia. In the year 2000, an addendum to the “how-to” suicide manual “Final Exit” suggested the use of an inert gas along with a plastic bag to induce death (Gilson et al., 2003). These methods, advocated by “right-to-die” societies, had both been uncommon methods of suicide in North America at the time (Bullock and Diniz, 2000; Haddix et al., 1996; Marzuk et al., 1993; Ogden and Hassan, 2011). However, shortly thereafter case reports began to emerge of suicide deaths by these means in North America (Gilson et al., 2003; Ogden & Wooten, 2002) and around the world (Auwaerter et al., 2007; Barnung et al., 2004; Grassberger and Krauskopf, 2007; Schon and Ketterer, 2007). Some studies have indicated that people obtain information about the use of these methods from the Internet, for example Wikipedia (Gunnell et al., 2015a, 2015b). The only Canadian study on the topic was a case series in British Columbia which identified 20 suicide deaths by helium asphyxia in the province from 1999-2007 (Ogden and Hassan, 2011). More recent, population-level analyses have demonstrated increases in suicide death by helium asphyxia in the U.S. (Azrael et al., 2016; Hassamal et al., 2015), the Netherlands (van den Hondel et al., 2016), Australia and Sweden (Austin et al., 2011), England and

Wales (Gunnell et al., 2015a) and Hong Kong (Chang et al., 2016) and have demonstrated a signal that the method may be spreading to Asia (Chang et al., 2016).

Similarly, the emergence of suicide by charcoal burning began in Asia with the first publicized story in Hong Kong in 1998 (Chang et al., 2010; Yip and Lee, 2007). Similar to the content of *Final Exit* (Humphry, 1991), the method was described in great detail and was also portrayed as being a painless and peaceful way to die (Chang et al., 2010; Yip and Lee, 2007). There was a subsequent rapid increase in suicide deaths by charcoal burning across Southeast Asia including Hong Kong and Taiwan where it became the most common method of suicide (Chang et al., 2014, 2010; Liu et al., 2007). In South Korea, the number of suicide deaths by charcoal burning rose from 34 in 2006 to 1,125 in 2012 (Choi et al., 2014). In many cases, the rise in suicide by charcoal burning was associated with an increased overall rate of suicide (Chang et al., 2014, 2010; Thomas et al., 2011; Yip et al., 2010; Yoshioka et al., 2016, 2014). People living in urban areas were found to be at higher risk likely because of greater access to both the charcoal itself and media exposures (Chang et al., 2010). Recent studies have also demonstrated a signal of an increase in the use of this method of suicide in England and Wales (Gunnell et al., 2015a) as well as the U.S. (Azrael et al., 2016).

The purpose of this study is to determine the extent to which these emerging methods may have spread to Toronto, Canada's largest city. Toronto is one of the most multicultural cities in the world, with 50% of its population born outside the country including a large Asian community (Statistics Canada, 2006). A community with these demographics in an urban centre with a large, active media market provides another opportunity to study this phenomenon. The a priori hypothesis of the study is that both helium and charcoal burning asphyxia suicide deaths will have increased over time. This research is intended to inform future efforts for early detection and intervention to prevent the spread of novel methods of suicide.

Methods

Suicide Death Data

The population of interest was all people who died by suicide in the city of Toronto from 1998-2015. Detailed information about these deaths was obtained through charts at the Office of the Chief Coroner of Ontario (OCC) using previously described methods (Sinyor et al., 2014). Basic demographic details (age, sex, marital status, living situation) and clinical information (presence of depression, bipolar disorder, schizophrenia, another mental disorder, a medical condition, past suicide attempts and contact with psychiatric services in the week prior to death) were collected. Note that clinical information was most frequently obtained from next of kin/coroner's interviews with people who knew the deceased. In some circumstances, if judged to be relevant for the death investigation, the coroner interviewed the deceased's physician(s) and/or reviewed medical/psychiatric records.

Deaths by inhalational asphyxia were divided into three groups: a) suicides by compressed gas (i.e. using helium or nitrogen), b) suicides by charcoal burning and c) suicides by motor vehicle exhaust. Any suicide death that did not assort into one of these groups was considered as a fourth group, suicide by other methods. Determination by the OCC of these causes of death is made by the combination of information at the scene of death, including location of the deceased and presence/configuration of lethal materials, forensic pathologist examination and, in some instances, toxicological evaluation which may include carbon monoxide/carboxyhemoglobin saturation. As OCC forensic pathologists have subspecialized expertise in identifying the cause of death, we relied on their determinations as definitive regarding the suicide method that led to death.

All deaths were coded for the presence of a "how-to" manual such as Final Exit in the deceased's possession/at the scene of death. For deaths by compressed gases, the origin/mode of purchase of the gas was identified, whenever available. Online informational sources used by the

deceased to inform the method used would also have been of interest; however these were not systematically abstracted by the coroner/were unavailable.

The OCC does not collect data on ethnicity however, given that the rise in compressed gas/charcoal burning suicide deaths began in East Asia, deaths by these methods were reviewed to determine if the investigation identified the deceased's ethnicity or whether the deceased's names indicated an East Asian or other ethnic origin according to a validated list of common names (Shah et al., 2010).

Statistical Analysis

Counts of suicide deaths by each method over time are presented descriptively, with change measured by dividing the 18 years of study into 6-year epochs (1998-2003, 2004-2009 and 2010-2015). Demographic and clinical characteristics of the three types of inhalational asphyxia and all other suicide deaths were compared using Analysis of Variance (ANOVA) tests and χ^2 tests for continuous and categorical variables respectively. Two-sample t-tests with unequal variance and χ^2 tests were used to identify significant, pairwise differences between groups when the global test showed significance. All statistics were performed using IBM SPSS Statistics 24 (SPSS Inc, Chicago, IL).

Results

From 1998-2015 there were 4,062 suicide deaths in Toronto of which 190 (4.7%) were by inhalational asphyxia. These 190 deaths included 78 (1.9%) by compressed gas, 75 (1.8%) by motor vehicle exhaust, and 37 (0.9%) by charcoal burning. Trends over time in inhalational suicide deaths by compressed gases and charcoal in relation to suicide deaths by motor vehicle exhaust and other methods are shown in Figure 1 as well as Table 1. In 1998-2003, 2004-2009 and 2010-2015, there were 9, 44 and 62 deaths respectively by compressed gas and charcoal combined. Comparing the first and last 6-year epoch, suicide deaths by helium asphyxia increased by 1075% while charcoal suicide

deaths increased 533% and suicide deaths by motor vehicle exhaust decreased by 78%. Suicide deaths by other methods and overall were relatively unchanged.

Demographic, clinical and suicide-specific data regarding suicide decedents are shown in Table 2. There was no difference in age between the groups but a higher proportion of males used compressed gas or motor vehicle exhaust gases than those who died by other methods (83.3% and 84.0% vs. 69.7%, both $p=0.01$). Twelve (15.4%) of those who died by compressed gases had a copy of the book *Final Exit* in their possession compared to 26 (0.07%) of those who died by other means ($p<0.001$). People who died by compressed gases and charcoal were both more likely to leave a suicide note (70.5% and 62.2% respectively) than those who died by motor vehicle exhaust or other means (33.3% and 29.8% respectively). Those who died by compressed gases were also least likely to have an identified history of a mental disorder (59.0%) or a past suicide attempt (15.7%). Fewer than five decedents in each of the inhalational asphyxia types had schizophrenia and fewer than five in each of these categories had contact with psychiatric services in the week prior to death (numbers suppressed).

Additional information about people who died by suicide via compressed gases and the circumstances surrounding their procurement of the gases are shown in Table 3. It was only possible to identify the ethnicity of the deceased in two thirds of cases, however the majority of these (30 cases; 57.7% of all compressed gas deaths where ethnicity was specified) occurred in Caucasians. In contrast, of the 14 out of 37 people who died by charcoal-burning whose ethnicity could be determined, all but one – 13 (92.8%) – were Asian. Of those who died by compressed gases, 50% had a previously identified, longstanding physical or mental health problem. The specific source of the tanks was mainly unknown/unidentified by the coroner, however, 23.1% of deaths involved a gas product designed for children's parties and multiple compressed gas tanks were found at the scene of death in 25 (32.1%) cases.

Discussion

This is the largest study to focus specifically on inhalational suicide deaths in Canada. It demonstrates that there has been a substantial rise over time in deaths by both compressed gases and charcoal burning accompanied by a numerically smaller reduction in deaths by motor vehicle exhaust. It showed that these deaths more commonly arose in males without a previously identified history of mental disorders, were frequently associated with suicide notes and that compressed gases were often purchased from local stores. There was also an indication that deaths by compressed gases occurred more commonly in Caucasians while deaths by charcoal burning were more common in Asians.

The proportion of suicide deaths by inhalational asphyxia is similar to what has been observed in England and Wales (Gunnell et al., 2015a) as well as the U.S. (Azrael et al., 2016; Cantrell and Lucas, 2014) and the pattern of an increase in suicide by helium accompanied by a reduction by motor vehicle exhaust is also consistent with prior research (Azrael et al., 2016) although these changes likely represent two different co-occurring phenomena (i.e. social contagion of the helium method vs. an increase in the proportion of motor vehicles fitted with catalytic converters (Studdert et al., 2010), respectively). Furthermore, those who died by compressed gas or charcoal burning in Toronto were more likely to be male and least likely to have a previously identified mental disorder or mental health contact which is similar to observations in Hong Kong and Taiwan which have been the epicenter of the charcoal burning suicide epidemic (Chen et al., 2015a). This has important public health implications given that men, as a group, are known to be less likely to engage in care (Galdas et al., 2005). Therefore prevention of these deaths is likely to require population-level means restriction and case identification strategies rather than a focus on existing clinical populations (Chen et al., 2015b; Yip et al., 2010). Case identification efforts could be implemented in workplace settings and through community agencies. Furthermore, efforts to ensure that the media do not report about this method at all and, in particular, if used in high-profile suicide deaths, are warranted (Chang et al., 2015).

While most previous studies have shown that inhalational asphyxia is more common in men, the relationship with age is less clear with some studies associating this method with older age (Bullock & Diniz, 2000; Haddix et al., 1996; van den Hondel et al., 2016) and some with younger age (Chang et al., 2016; Chen et al., 2012; Gunnell et al., 2015a; Howard et al., 2011; Kato et al., 2013). This study found no difference in age between any group of suicide decedents. Likewise, this study supports the previous observation that people dying by emerging methods of asphyxia may be less likely to suffer from substance use problems and psychiatric illnesses compared to people dying by other methods (Kato et al., 2013; Law et al., 2011).

The fact that these decedents had fewer identified and treated mental disorders may also help to explain the greater rates of suicide notes as this group may have had a greater motivation to express previously unrecorded explanations for their suicidal behaviour. The larger proportion of people who left suicide notes might also be an indication that these deaths are more deliberate/less impulsive than suicides by other methods. High rates of suicide notes in decedents by helium asphyxia have been reported previously in the U.S. and the Netherlands (Howard et al., 2011; van den Hondel et al., 2016).

In general, those who died by compressed gases and charcoal burning were similar in terms of demographic and clinical profiles with the notable exception of the former group being more Caucasian and the latter more Asian. This suggests that these two methods may reflect cultural manifestations of a similar phenomenon given that Final Exit first emerged in the West while charcoal burning emerged in Southeast Asia. It may also simply reflect that the “cognitive availability” (Florentine & Crane, 2010) of each method is region-specific. It is also notable that the majority of decedents had an identified history of mental disorders while relatively few had identified medical conditions. The stated initial purpose of Final Exit was to aid people with terminal illnesses in dying (Gilson et al., 2003), however it is apparent that the methods described in that book as well as other methods of inhalational asphyxia are far more frequently used in people with no serious physical health problems.

Although the source of the compressed gases was mainly undetermined, in the 26% of cases where it was identified, all were purchased from a local store. This demonstrates a clear potential avenue for future suicide prevention/means restriction efforts. A means restriction program in Taiwan mandating that barbeque charcoal be taken off open shelves at stores and moved to locked storage resulted in a 30% reduction in deaths by this method with no compensatory increase by other methods (Chen Y.Y. et al., 2015b). A similar approach could be taken for stores selling compressed gases. An additional option would be regulations which require the addition of oxygen to compressed gas tanks at a concentration that would render inhalation non-lethal. Such efforts, coupled with increased surveillance and public health attention to emerging methods of suicide are considered the optimal approach to preventing these deaths (Yip et al., 2017, 2010).

One of the key questions that this study cannot answer is whether rates of suicide in Toronto would have been lower in the later years examined were it not for the emergence of these novel methods. Regardless, suicide rates in Canada and much of the developed world have diminished incrementally over a similar timespan (WHO, 2014) and efforts to restrict access to these emergent methods both physically and in terms of awareness through the encouragement of media to follow safe reporting guidelines are prudent to ensure that this trend continues.

Limitations

This study had several important limitations. First, it only examined deaths ruled as occurring by suicide by the coroner. Notably, however, this almost certainly captures all or nearly all deaths by gasses as these would be unlikely to be ruled as accidental, natural or as homicide. Given that toxicology was not performed on all deceased, we cannot rule out the possibility that a small number of deaths that appeared to be caused by inhalational asphyxia were caused by exposure to other substances. Second, it examined Canada's largest city only. Although these deaths may occur more

frequently in urban environments and the focus on a dense metropolis may have advantages in terms of a centralized means restriction strategy, this study is unable to identify whether trends observed in Toronto are generalizable to other Canadian cities or in regions. Note also that the data presented here are suicide counts that may be influenced both by the size and ethnic composition of the population which change over time. The population of Toronto grew by 12.5% from approximately 2.4 million people in 1998 (Statistics Canada, 2001, 1996) to approximately 2.7 million people in 2015 (Statistics Canada, 2016) with a growing Asian population. This may partly help to account for the increase in charcoal burning deaths over time. Third, as clinical information about the deceased was often obtained from relatives and acquaintances of the deceased and not systematically from medical records, data regarding mental and physical disorders should be interpreted with a note of caution and identified rates should be considered as underestimates. Finally, important details such as ethnicity and specific details of procurement of suicide methods were not systematically available in coroner records and therefore the data presented regarding those factors must be interpreted with a note of caution.

Conclusion

This study demonstrates that novel methods of suicide by inhalational asphyxia have emerged in Canada's largest city, consistent with what has been reported in other countries around the world. It suggests that increased and timely surveillance of these deaths as well as means restriction efforts aimed at reducing access to compressed gases and charcoal should be explored in Toronto. Early detection and intervention are particularly crucial for novel suicide methods such as these to avoid their broad dissemination. Efforts to engage with the media and internet providers/groups that host web pages are also warranted given that these are the primary "vectors" of social contagion of novel methods. Finally, the results here support the need for efforts to identify and engage men in care since they die by these methods at disproportionately high rates.

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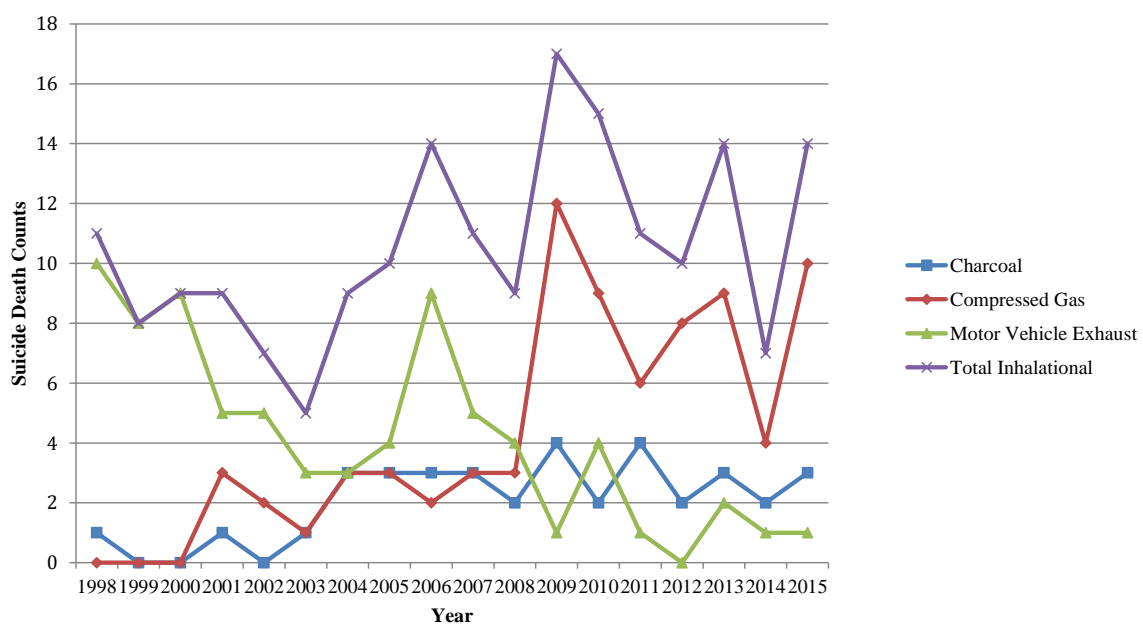
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Figure 1. Suicide Deaths by Comprssed Gas*, Charcoal, Motor Vehicle Exhaust and by All Inhalational Means in Toronto (1998-2015)



*Note: Compressed gases = 72 deaths by helium and 6 deaths by nitrogen

Table 1. Time trends in suicide deaths in Toronto by compressed gases, charcoal, motor vehicle exhaust and other methods (1998-2015).

Suicide Method	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total	Change 1998-2003 vs. 2010-2015
Helium	0	0	0	2	2	0	3	3	2	3	3	11	9	6	8	9	4	7	72	+1075%
Nitrogen	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	3	6	+150%
Charcoal	1	0	0	1	0	1	3	3	3	3	2	4	2	4	2	3	2	3	37	+533%
Motor vehicle Exhaust	10	8	9	5	5	3	3	4	9	5	4	1	4	1	0	2	1	1	75	-78%
Other Methods	228	210	238	183	196	249	214	200	202	215	192	218	207	194	218	235	231	242	3872	-1.8%
Total	239	218	247	192	203	254	223	210	216	226	201	235	222	205	228	249	238	256	4062	+3.3%

Table 2. Comparison of characteristics of suicide by compressed gas, charcoal-burning, motor vehicle exhaust suicides, and all other suicides in Toronto, 1998-2015.

Characteristic	A	B	C	D	χ^2 or F	df	p	A vs B	A vs C	A vs D	B vs C	B vs D	C vs D
Characteristic	Compressed gas suicides (n = 78) ^a	Charcoal-Burning suicides (n = 37)	Motor vehicle exhaust suicides (n = 75)	All other suicides (n = 3872) [§]									
Mean age (y, range)	45 (15-81)	46 (16-86)	51 (18-89)	47 (12-97)	1.48	3	NS						
	n (%)	n (%)	n (%)	n (%)									
Male sex	65 (83.3)	32 (86.5)	63 (84.0)	2703 ^B (69.7)	18.21	6	*	NS	NS	*	NS	NS	*
Married	16 (20.5)	12 (32.4)	24 (32.0)	1004 (26.0)	3.42	3	NS						
Living alone	37 (47.4)	15 (40.5)	35 (46.7)	1626 (42.1)	1.56	3	NS						
Final Exit	12 (15.4)	—†	—†	26 (0.07)	179.40	3	***	*	***	***	NS	NS	NS

Presence of suicide note	55 (70.5)	23 (62.2)	25 (33.3)	1154 (29.8)	76.32	3	***	NS	***	***	**	***	NS
Past suicide attempts	12 (15.4)	14 (37.8)	18 (24.0)	1063 (27.5)	8.14	3	*	*	NS	*	NS	NS	NS
Depression	34 (43.6)	18 (48.6)	50 (66.7)	2020 (52.3)	8.78	3	*	NS	**	NS	NS	NS	*
History of Substance Abuse	5 (6.4)	— †	12 (16.0)	776 (20.1)	12.86	3	*	NS	NS	**	NS	NS	NS
Identified history of mental illness	46 (59.0)	23 (62.2)	58 (77.3)	2936 (76.0)	15.63	3	**	NS	*	**	NS	NS	NS
Presence of any medical condition	25 (32.1)	6 (16.2)	22 (29.3)	1336 (34.5)	6.48	3	NS						

§ There were 3878 cases, but data was only available for 3872; for age and male, there are 3872 cases, but for all other characteristics, there are 3866 cases because data is missing for 6 cases.

† Values <5 were suppressed due to low sample size.

^a Includes Helium (n = 72) and Nitrogen (n = 6).

^β Sex unknown for two cases.

NS = not statistically significant.

* Significant at $p < 0.05$

** Significant at $p < 0.01$

*** Significant at $p \leq 0.0001$

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Table 3. Additional Demographic Characteristics and Suicide-Specific Characteristics of People Who Died by Compressed Gas[§] (n = 78) in Toronto (1998-2015).

Characteristic/Variable	Compressed gas suicides (n = 78) [§] n (%)
Ethnicity	
Caucasian	30 (38.5)
Asian	14 (17.9)
Other	8 (10.3)
Ambiguous/Undetermined	26 (33.3)
Long standing clinical condition[†], n (%)	
Yes	39 (50.0)
No	37 (47.4)
Unclear/Unknown	2 (2.6)
Source of compressed gas tanks, n (%)	
A. Party Supply Store	10 (12.8)
B. Large Department Stores	6 (7.7)
C. Other Stores	4 (5.1)
E. Unknown	58 (74.4)

Tank brand	
Children's Party Products	18 (23.1)
Unclear/Unknown	59 (75.6)

Number of Tanks Present	
1	53 (67.9)
≥ 2	25 (32.1)

[§] Includes Helium (n = 72) and Nitrogen (n = 6).

[†] Previously detected mental or physical health problem that is of a chronic nature (i.e. distinct from an acute illness or short-term condition)