

Brain weight in suicide

An exploratory study

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Background There is little available literature on the effect of suicide methods on brain weight.

Aims To explore variations in post-mortem brain weight in different methods of fatal self-harm (FSH) and in deaths from natural causes.

Method A review of a sample of coroners' records of elderly persons (60 and above). Verdicts of suicide, misadventure and open verdicts were classified as FSH. Post-mortem brain weight for 142 FSH victims and 150 victims of unexpected, sudden or unexplained death due to natural causes, and from various methods of FSH, were compared.

Results Brain weight of victims of FSH was significantly higher than of those who died of natural causes ($P < 0.01$); brain weights in both groups were within the normal range for this age group. There was no significant difference in brain weight between different methods of FSH ($P > 0.05$).

Conclusions The findings require critical examination and further research, to include data from younger age groups. A regional or national suicide neuropathological database could be set up if all victims of FSH underwent routine neurohistochemical post-mortem examination.

Declaration of interest None.

The weight of the brain is approximately 1.4% of that of the body, and it varies with age and gender (Ludwig, 1979). The mean weight of 'wet' autopsy brain of an adult male is 1300–1450 g (female, around 100 g less), with an average increase of 8% after fixation (Knight, 1996). The mean brain weight of men aged 60–70 is 1323 g (range 1018–1600) and for ages 70–85, 1279 g (1039–1485); for women aged 60–70, mean brain weight is 1178 g (920–1372) and for ages 70–85, 1121 g (852–1370) (Knight, 1996). Brain weight has been explored in normal ageing as well as in a number of psychiatric conditions. Mueller *et al* (1998) reported that insignificant brain volume loss is observed over time in healthy people aged over 65. This suggests that large changes seen in cross-sectional studies reflect the presence of preclinical dementia in older groups (Mueller *et al*, 1998). Courchesne *et al* (1999) reported that post-mortem brain weights of people with autism were similar to those of the normal population. Johnstone *et al* (1994) found that decreased brain weight in schizophrenia was significantly related to poor premorbid global function and to more severe negative symptoms. Lower brain weights were also reported by Pearlson & Warren (1989) in Down's syndrome and by Nochlin *et al* (1993) in Alzheimer's disease. Brown *et al* (1986) reported that the decrease in brain weight in schizophrenia was less than in Alzheimer's disease and Huntington's chorea. Hakim and Mathieson (1979) reported a significantly reduced weight in brains from Parkinson's disease cases, compared to a matched control group. Harper and Blumberg (1982) reported that the brain weight of alcohol-dependent males was significantly less than that in a normal population, both for brains with alcohol-related nutritional damage (Wernicke's encephalopathy) and brains which appeared 'normal' macroscopically and microscopically.

We found only one published article about the effect of various methods of fatal self-harm (FSH) on brain weight. Schroder and Saternus (1983), investigating changes in the brain caused by suicidal hanging, found that the brain weight – both for typical and atypical hanging – was greater in all age groups than the average found in clinical autopsy. Investigating the effect of hypothalamic–pituitary–adrenal dysfunction in major depression and suicidal behaviour, Szigethy *et al* (1994) found that the mean left adrenal weight was significantly higher in suicide victims, but these authors did not comment on brain weight.

In this study we attempt to explore whether brain weight measured post-mortem varies with different methods of FSH and whether it differs from that of persons who died of natural causes.

METHOD

We carried out a retrospective review of records of coroners' inquests on older people. In an attempt to reduce any ascertainment bias of suicide, we use the term 'fatal self-harm' (FSH) to include all cases where the coroner's verdict was suicide, cases who killed themselves but in which the coroner returned an open verdict because of insufficient evidence, and those who had committed some deliberate act which resulted in death, but the apparent intent to die was absent ('misadventure').

Fatal self-harm data

Data were extracted from coroners' records of all deaths of persons aged 60 years or over from 1994 to 1998 occurring within the North Cheshire and Birmingham districts, for those classified as having committed suicide (ICD-9 E950–959), and for those for whom an open verdict or a verdict of misadventure was returned (ICD-9 E980–989; World Health Organization, 1978), from two Coroner's Offices, in Warrington (35% of the sample) and Birmingham (65%). Information extracted included demographic data, method of death and coroner's verdict, and brain weight as recorded by the pathologist. The brain weights of people aged ≥ 60 whose deaths were unexpected, sudden or unexplained (thus requiring a post-mortem), but attributed to natural causes, were also collected for comparison. Unfortunately, data relating to body weight and height were not available. The

deceased were matched by obtaining equal means and variances of the two groups for age by gender. For all subjects, whether death was due to natural causes or FSH, post-mortem examination was reported to have been carried out within 6–12 hours of death. All brain weights included in the study were reported as 'wet' autopsy weights where no formalin fixation was used.

RESULTS

Data were available on the weight of 292 post-mortem brains: 87 male (64%), 105 female (36%). Of these, 150 (51%) were deaths due to natural causes: 107 male (71%), 43 female (29%); and 142 (49%) due to FSH: with a suicide verdict in 93 cases (55 male (59%), 38 female (41%)) and an open verdict in 49 cases: 25 male (51%), 24 female (49%). The mean age of the sample was 72 years (s.d.=8): male 71.7 (s.d.=8) and female 12.9 (s.d.=8). Men who died of FSH ($n=80$) or natural causes ($n=107$) had a matched mean age of 71.5 years (s.d.=7) and for women, the matched mean age was 72.9 (s.d.=8) for both FSH ($n=62$) or natural causes ($n=43$).

Of the methods of fatal self harm, 39% were overdose, 24% hanging, 9% drowning, 16% asphyxia or inhalation of carbon monoxide and 12% were other means (mostly violent). The natural causes of deaths were cardiac or cardiovascular (80%), respiratory (15%) and cerebral haemorrhage (5%). The mean brain weight

for the entire sample was 1291 g (s.d.=124) (median 1280) (males, 1310 g (s.d.=122); females, 1258 g (s.d.=119)). Table 1 gives the basic statistics.

Figure 1 is a box plot graph of the highest and lowest brain weights; the median is a thick line inside each box, which contains 50% of cases within the interquartile range. The central position of the median indicates a normal distribution of weights, with positively skewed distribution in some FSH methods involving small numbers.

Table 2 summarises the distribution of brain weight in FSH cases in relation to the method of death. A suicide verdict appears to have been returned more frequently in cases of FSH by hanging and asphyxia using a plastic bag; but a suicide verdict was also returned in all incidents of FSH by wounding, electrocution and carbon monoxide poisoning using car exhaust. An open verdict was returned more frequently in cases of death by drowning, being killed by a train, jumping from a height and setting fire to oneself. Electrocution, car exhaust and setting fire to oneself were methods used only by men.

Means of brain weight were compared using the *t*-test for the following groups:

(a) suicide ($n=93$) *v.* natural death ($n=150$): mean brain weights 1352 *v.* 1238 g, respectively ($t=-8$, $P<0.001$, 95% CI for mean difference -141.8 to -86.6 ; females only $t=-6.1$, $P<0.001$; males only $t=-7.45$, $P<0.001$);

(b) open verdict ($n=49$) *v.* natural death ($n=150$): mean brain weights 1338 *v.* 1238 g, respectively ($t=-6$, $P<0.001$, 95% CI for mean difference -133.4 to -67.8 ; females only $t=-5.5$, $P<0.001$; males only $t=-4.9$, $P<0.001$);

(c) suicide ($n=93$) *v.* open verdict ($n=49$): mean brain weights 1352 *v.* 1338 g, respectively ($t=0.6$, $P=0.5$, 95% CI for mean difference -32.6 to 59.9 ; females only $t=-0.12$, $P=0.9$; males only $t=0.5$, $P=0.5$); and

(d) all FSH verdicts ($n=142$) *v.* natural death ($n=150$): mean brain weights 1347 *v.* 1238 g, respectively ($t=-8.4$, $P<0.001$, 95% CI for mean difference -135.2 to -83.8 ; females only $t=-6.1$, $P<0.001$; males only $t=-7.45$, $P<0.001$).

Comparison of the means seems to suggest that the brain weight of deceased elderly cases of suicide or an open verdict after FSH was significantly higher than that of those who died naturally. There was no significant difference in brain weight between the two groups, indicating that open verdict and suicide cases belong to the same population within the FSH group.

Nor was there any significant difference between mean brain weights for all methods of death in the FSH group (ANOVA $P>0.05$), nor any significant variations in brain weight with cause of death within the comparison group (cardiac, cardiovascular or respiratory causes). The brain weights of all those who had died naturally or fatally harmed

Table 1 Brain weight (g)

Method of death	No.	Median	Mean	s.d.	Range	Male			Female		
						<i>n</i>	Mean	s.d.	<i>n</i>	Mean	s.d.
Natural causes	150	1240	1238	37	1050–1420	107	1260	79	43	1184	82
Fatal self-harm	142										
Overdose	55	1344	1322	119	960–1558	20	1352	79	35	1305	127
Hanging	34	1383	1394	159	1050–1780	29	1409	167	5	1309	54
Drowning	13	1392	1321	145	985–1473	7	1339	34	6	1299	126
Run over by train	3	1355	1341	27	1310–1359	2	1334	34	1	1335	
Asphyxia	16	1349	1341	111	1164–1497	4	1445	30	12	1307	107
Jumping from height	5	1315	1310	81	1207–1398	4	1319	93	1	1315	
Electrocution	3	1347	1286	109	1160–1357	3	1286	109	0	0	0
Car exhaust	7	1379	1409	159	1215–1698	7	1409	59	0	0	0
Knife	4	1400	1391	100	1260–1505	2	1400	70	2	1382	173
Set fire to self	2	1342	1342	74	1290–1395	2	1342	74	0	0	0

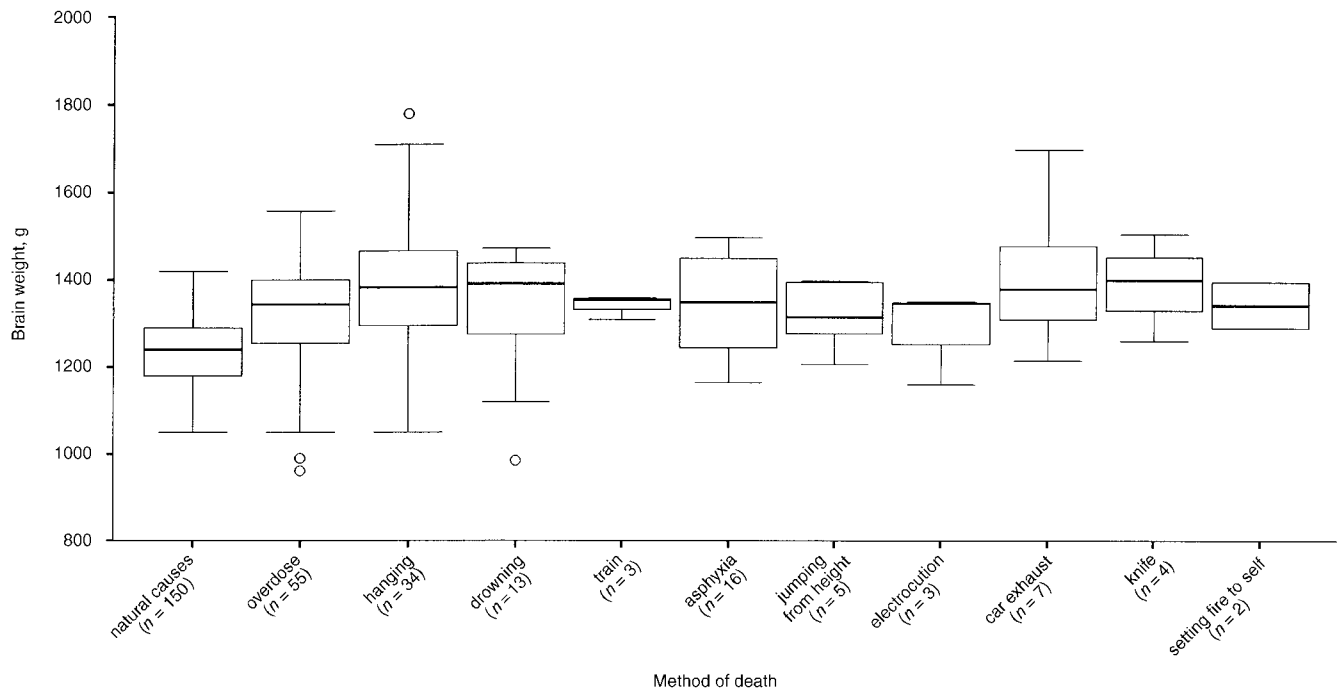


Fig. 1 Brain weight in cases of fatal self-harm.

Table 2 Mean brain weight (g) in fatal self-harm (FSH)

Method of FSH	Men				Women			
	Suicide		Open verdict		Suicide		Open verdict	
	n (%)	Mean	n (%)	Mean	n (%)	Mean	n (%)	Mean
Overdose	14 (70)	1330	6 (30)	1345	19 (54)	1311	16 (46)	1299
Hanging	24 (83)	1403	5 (17)	1435	5 (100)	1309		
Drowning			7 (100)	1339	3 (50)	1283	3 (50)	
Run over by train	1 (50)	1359	1 (50)	1310			1 (100)	1316
Asphyxia	3 (75)	1444	1 (25)	1450	9 (75)	1291	3 (25)	1355
Jumped from height	1 (25)	1207	3 (75)	1359			1 (100)	1315
Electrocution	3 (100)	1286						
Car exhaust	7 (100)	1409						
Knife	2 (100)	1400			2 (100)	1382		
Set fire to self			2 (100)	1342				

themselves were nevertheless within the expected normal range for this age group.

DISCUSSION

Limitations of the study

A number of factors may have influenced the study findings and should be considered when interpreting the results.

(a) Bias may have resulted from the method the pathologists used in removing the brains for examination. The method described in Knight's (1996) forensic textbook seems to be an internationally accepted standard used by pathologists. However, any such bias is likely to have been random, thus equally affecting the groups of FSH and those who died naturally.

(b) Information bias might have arisen from the many different pathologists' reports used for data collection, as well as from the records of two different coroners, with some variation in the quality and style of reporting. However, all the coroners' records reviewed were quite detailed, accurate and highly organised. Also, the FSH and control groups were equally distributed between the two coroners

(35% *v.* 65%, for both cases and controls).

- (c) The time between death and post-mortem examination might have varied. However, in all subjects, whether death was due to natural causes or FSH, post-mortem examination was reported in the records to have been carried out within 6–12 hours of death.
- (d) Bias may have resulted from variations in method, cause and, in particular, mode of death. In almost all FSH cases, death was sudden or rapid. Deaths due to natural causes were selected from cases of unexpected or unexplained death, mostly either rapid or sudden, referred for hospital autopsies or coroner's post-mortem. It was difficult, if not impossible, to match the two groups accurately by mode of death, other than in general terms (rapid as opposed to slow or prolonged). In the majority of natural deaths, the direct cause was reported as cardiovascular, which would have been rapid.
- (e) Although cases were matched for age, the possibility of preclinical dementia in the group of hospital autopsies cannot be excluded. This might have led to somewhat lower brain weights in this group.
- (f) The unavailability of pre-study data to determine sample size and study power may limit the study's inferential value. The difference in mean values may have been the result of bias (a), above, rejecting a true null hypothesis of no difference. However, an adequate level of significance was used to guard against such error.

Interpretation of the findings

Brain weights vary with age, gender, cause and mode of death and what happened to the brains after death (Knight, 1996). The brain is usually examined immediately ('wet cutting') or is suspended in formalin until fixed, a process which takes several weeks. In the majority of autopsies there is no real need for fixation if no cerebral lesions are suspected, expected or apparent on external examination (Knight, 1996). In this study all brain weights were reported as 'wet' autopsy weights where no formalin fixation was used, so increased weight cannot be attributed to the fixation process.

The increase in brain weight in association with histological signs of oedema in

CLINICAL IMPLICATIONS

- Brain weight in all methods of fatal self-harm (FSH) was found to be significantly greater than in death from natural causes. There was no significant difference in brain weight for different methods of FSH. Brain weights for all those who died naturally or fatally harmed themselves were nevertheless within the expected normal range for this age group.
- This unexpected finding requires critical examination, particularly in view of the reported bias, which may have significantly influenced the results.
- We propose a confidential neuropathological database for all FSH incidents, containing classified neurohistochemical findings.

LIMITATIONS

- Bias may have resulted from the method which the pathologists used in brain removal for examination, the fact that many different pathologists' reports were used for data collection, variations in method, cause and mode of death, and the possibility of the presence of preclinical dementia in some cases.
- Mode of death as a confounder is probably a crucial factor that we were unable to control due to the nature of data collection.
- The undetermined study power may limit its inferential value.

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hanging was put down to a definite terminal post-mortem brain swelling, as it is known in all forms of peracute death caused by unrestricted arterial flow but reduced venous return from intracranial sinuses (Schröder & Saternus, 1983). Cerebral oedema can be caused by hypoxia, intracranially due to direct or indirect trauma, or from any part of the body, and, whether traumatic or hypoxic, the cerebral oedema is self-potentiating and develops surprisingly quickly (Knight, 1996). The neuropathological findings in irreversible coma give similar findings of brain swelling and softening.

Walker *et al* (1975), in their study on cerebral survival, reported that brain weight fluctuated, increasing during the first 24 hours after resuscitative measures were started, falling on the second day and then rising again. Patients in whom resuscitation was stopped on the basis of

presumed brain death had on the average heavier brains (70 g, $P < 0.01$).

Respirator brain syndrome is described by Walker *et al* (1975) as a dynamic process that may progress until pulmonary or cardiac disturbances terminate the patient's life or until resuscitation is stopped. The changes seen in respirator brain result from impaired cerebral blood flow causing brain swelling, complicated by concurrent post-mortem changes (Moseley *et al*, 1976). This process requires approximately 24 hours for maturation (Walker *et al*, 1975). Factors contributing to respirator brain are acute ischaemia, acidosis, hypoxia, low systolic blood pressure, subnormal temperature, history of respiratory dependency and extensive tissue necrosis (Moseley *et al*, 1976), and probably present before death in some cases. Although a mechanism similar to that in respirator brain syndrome may

provide partial explanation for our findings, it cannot fully explain the relative increase in brain weight in those who died of fatal self-harm, regardless of the method of death, compared to those who died naturally.

The element of bias in the study, although systematic, probably occurred randomly in both groups, so it is unlikely to be solely responsible for the study findings. Moreover, the sample included only persons over the age of 60, so the results cannot be generalised to younger age groups. However, it may prove difficult to obtain enough young subjects who have died naturally to match for age with those who die of FSH. Prospective studies with carefully selected and matched cases and controls may overcome the limitations encountered in this retrospective exploratory study. Data could be obtained from routine neuropathological examination, macroscopically and microscopically assessing the extent of cerebral oedema, brain chemistry and the state of its receptors at death; such investigations should be carried out as a matter of course for all victims of fatal self-harm. As we are dealing with small number of cases (9.7 per 100 000) the cost would not be expected

to be prohibitive, and the process is certainly feasible.

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