

The unseen casualties of the First World War: insights from a randomly selected military sample

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ABSTRACT

AIMS: Studies of the morbidity burden of military personnel participating in the First World War (WWI) have tended to focus on specific outcomes (e.g., injuries). Therefore, we aimed for a more complete assessment.

METHODS: From a random sample of active war service-exposed New Zealand WWI veterans used in previously published work, we examined a random subsample of 200 personnel. Data on diagnoses, hospitalisations and outcomes were extracted from the online archival military files.

RESULTS: These personnel experienced a very high morbidity burden with 94% having at least one new condition diagnosed during their military service (mean: 2.4 per individual; range: 0 to 8). The relative severity of these conditions was reflected by the high level of hospitalisation (89% at least once; mean: 1.8 hospitalisations for new conditions per individual) and 59% of personnel being deemed no longer fit for military service at some stage. More of the new diagnoses were for infectious diseases than for conflict-related injuries (117 vs 50 cases per 100 personnel). Respiratory conditions such as influenza, pneumonia and tuberculosis affected 33% of personnel, and 14% were diagnosed with sexually transmitted infections. Diseases reflecting hazardous environmental conditions were relatively common e.g., for dysentery/gastroenteritis in 12% and scabies in 5% of personnel. Diagnoses suggestive of post-traumatic stress disorder (PTSD) were present in 10% and chemical warfare injuries in 6%.

CONCLUSIONS: The overall morbidity burden of this military force in WWI was very high, and much higher than the previous official estimates.

Introduction

The First World War (WWI; 1914 to 1918) caused a substantial burden of injury and disease among participating military personnel. The most common injuries were caused by weapons (e.g., shrapnel from artillery, bullets and grenades). These injuries ranged from minor wounds up to those requiring limb amputations and causing permanent disability (e.g., blindness, deafness and traumatic brain injury).

Reviews have covered other health conditions in these personnel, including: the effects of the 1918 influenza pandemic on United States (US) and other soldiers;^{1,2} the occurrence of malaria;³ the (re)emergence of trench fever;⁴ trench foot and other trench diseases;^{5,6} and infectious diseases.⁷ Reviews of mental health impacts have included the psychological effects on medical personnel involved,⁸ shell shock and other psychoneuroses.^{9,10}

For New Zealand, there were an estimated 98,950 military personnel who served overseas in WWI, and 7,036 who served on home territory in the New Zealand Expeditionary Force (NZEF) for a

total of 105,986.¹¹ An estimated 18.2% died during the war and up to the end of 1923 (with this period used in the official New Zealand *Roll of Honour*¹¹). The official number of personnel wounded or suffering illness was 41,317 (equivalent to 39.0% of NZEF personnel). However, this number included “*all those removed from the front-line for medical treatment*”, as well as including repeat hospitalisations of soldiers, so it was more “*than the number of ‘wounded men’ per se*”.¹¹

These estimates do not include the more than 12,000 New Zealanders who served separately with other military forces during this war.¹² We also suspected that the official number of those wounded or suffering illness would be far below the level of overall morbidity that could be found upon examining military records for individual personnel—as found in a study of New Zealand personnel who served overseas in the South African War.¹³

The New Zealand military personnel were predominantly volunteers, though 26.0% were conscripted.¹⁴ Previous studies of this military population have focussed on their overall life-span,^{15–17} but also aspects of their injury burden.^{18,19}

The infectious disease burden included that from pandemic influenza,^{20–23} dysentery,²⁴ sexually transmitted infections²⁵ and disease outbreaks in training camps.²⁶ Other health aspects studied include the poor nutrition (e.g., at Gallipoli),²⁷ oral health²⁸ and mental health.^{29,30} A wide range of health conditions were described in an official report published soon after the war³¹ and a book details the medical services for the NZEF.³² Other works cover a range of different health conditions.^{33–36}

There is evidence of persisting disabilities after the war from the war pension data for New Zealand. As of 31 March 1921, a total of 40,227 veterans had lodged claims for war pensions for war-related disability and 17,612 dependents had also lodged war pension claims (for the period September 1915 to 1921).³⁷ Of all these claimants, 51,711 (or 89% of the total of 57,839) were granted war pensions (with this proportion not given separately for veterans vs dependents). Studies have also indicated elevated post-war morbidity in the veteran population. A cohort study following returned NZEF personnel across their remaining lifetimes found that 1.7% committed suicide.³⁸ Those who had been wounded, sick or medically discharged were found to have a significantly higher chance of suicide. Another study reported elevated suicide rates among these veterans compared to civilian men in the same age cohort during the 1920s and subsequent decades.³⁹ Other work has found death certificates of veterans that are suggestive of post-war deaths from suicide and alcoholism that could have been war related, along with deaths associated with operations on wounds and “war disability”.¹⁵

But despite all this work, it remains unclear what the overall injury/disease burden was for the New Zealand military personnel in this war. Similarly, for detail on the seriousness of the conditions e.g., as determined by hospitalisation. We therefore aimed to assess this burden with an in-depth examination of a random selection of military personnel from a national military force: that for Aotearoa New Zealand.

By way of further background, the NZEF mainly fought in Europe on the Western Front, but was also part of campaigns in the Middle East (Gallipoli and Palestine).⁴⁰ After its experience of fierce fighting at Gallipoli (1915), the newly formed New Zealand Division was sent to the Western Front in early 1916. It was initially assigned to a relatively quiet sector of the front at Armentières. This was to allow the troops to acclimatise and to familiarise themselves with the new warfare

conditions on the Western Front. Following this, they were then dispatched to significant sectors of the Western Front, participating in major battles such as those at the Somme (1916), Messines (1917), Passchendaele (1917), the German Spring Offensive (1918) and the Hundred Days final offensive. These were among the most intense and pivotal campaigns of WWI. The last military action on the Western Front for the New Zealanders was the liberation of the town of Le Quesnoy (where the New Zealand Liberation Museum will be opened in October 2023). A map showing relevant areas for the New Zealand military on the Western Front is available here: <https://nzhistory.govt.nz/media/photo/western-front-1916-17-map>.

Methods

Sample selection

The sample was derived from a previous study on a random sample of NZEF participants in WWI.¹⁷ From this larger sample we randomly selected 200 personnel for the in-depth analysis of their morbidity experience (for further details see the Appendix).

Data collection

All the socio-demographic data (including ethnicity and occupational class) were collected, as per the previously published study,¹⁷ as were military rank and participation in previous and subsequent wars. Added to this were data on new diagnoses, hospitalisations for new conditions and discharges from the military on medical grounds (all from the online archive of military files⁴¹). These files were almost all hand-written, often in difficult conditions at battalion or similar level.

On occasions, the paucity of details in the military files on health conditions required some assumptions, as follows:

- Where a condition could plausibly have been related to subsequent relapses or sequelae, we did not count these sequelae conditions separately. For example, a reference to “debility” that was followed several months after “influenza” or “dysentery” was assumed to be sequelae of one of these earlier diagnoses.
- For hospitalisations, we also distinguished between those for new conditions as opposed to those related to transfers to other facilities (e.g., from hospital to convalescent facility) or ongoing treatment for a

previously identified condition. We collected data on all admissions to hospitals, hospital ships and convalescent care facilities, but did not count visits to field ambulance units or casualty clearing stations that did not result in hospitalisation. To facilitate the data collection process, a detailed list of terms and acronyms used in the military files was compiled beforehand (see the Appendix).

- Where a particular diagnosis was first made after military service was completed e.g., a diagnosis of “shell shock” by a medical board after the war, we assumed that this condition had commenced while still in military service.
- The timing of “frontline” status was established by military file entries such as: “joined battalion” or battery or similar frontline unit (typically after periods in training or in the “rear”).

Other data sources that were occasionally consulted were online obituaries (e.g., in the dataset: Papers Past [<https://paperspast.natlib.govt.nz/>]).

Inter-observer reliability assessment for data collection

As the data extraction was first done by a single author, two other authors with experience in work with NZEF records each independently re-examined 10 randomly selected additional files each (to make up a 10% sample). The assessment compared the new diagnoses, the new hospitalisations and samples of extracted numerical data.

Data analysis

Data were collated in a Microsoft Excel file and univariate analyses were conducted using EpiInfo v7.1.5.2. Lifespan comparisons for different groups used analysis of variance (ANOVA).

Ethics statement

Ethical approval for this study was provided through the University of Otago Human Ethics Committee process (Category B Approval, D22/030).

Results

Inter-observer reliability assessment

Based on the two subsequent observers independently examining a 10% sample of the data, the following sensitivity estimates were obtained

for the first and main observer (when the “true” denominator is assumed to be that from all observers combined): 89% (41/46) for the number of new conditions; 91% (39/43) for the number of hospitalisations for new conditions; 84% (21/25) for the number of war theatres; 100% (19/19) for the correct date of death (when available from this source); and 100% (20/20) for length of stay overseas. Errors were made by the main observer for an incorrect “unfit status” (5%, 1/19) and for one diagnosis (2%, 1/46, where the words disability and diabetes were confused with each other).

Characteristics of the studied population

The average age of this randomly selected sample was 25.4 years (at the start of the war) and they were nearly all of European ethnicity (i.e., only 2.5% were Māori) (Table 1). The occupational class was dominated by the lower three groupings (54%) and military rank was predominantly in the lowest rankings (88%). By the end of 1916, 48% had been to a frontline position, and by the end of the war, 91.5%. The mean length of war participation was 2.6 years and the most common theatres of war were the Western Front (74%) and then the Middle East (Egypt, Sinai and Palestine) at 22%.

Morbidity burden

The great majority (94%) of this study population had at least one non-fatal new condition diagnosed and 89% had at least one hospitalisation for a new condition (Table 2). Indeed, the average participant had 2.4 new diagnoses and 1.8 hospitalisations for new conditions during their military service. This equated to 0.9 new conditions and 0.7 hospitalisations for new conditions per year of military service.

In terms of specific conditions, 42% of the personnel experienced at least one conflict-associated injury event (Table 3; Figure 1). Injuries from chemical warfare (gas poisoning) were experienced by 6% of personnel. But most of the new diagnoses were for infectious diseases, followed by the grouping of “other causes” (e.g., mental health) and then conflict-related injuries (117, 74 and 50 cases per 100 personnel respectively).

Respiratory conditions (including influenza, pneumonia, bronchitis and tuberculosis) alone impacted around a third of personnel (33%), with influenza being diagnosed in 19%. Sexually transmitted infections affected 14% of personnel (16 cases per 100 personnel), with gonorrhoea being the most common specified type.

Diseases typically reflecting hazardous environmental conditions were relatively common

Table 1: Demographic characteristics and military experience of the random selection of 200 male New Zealand military personnel participating in the First World War (for those travelling overseas, who were alive on 1 January 1919, and for whom age at death could be established).

Characteristic	Number	Other data
Demographics		
Mean age (years) at the start of the war (28 July 1914)	25.4	SD=6.95
Median age (years) at the start of the war (28 July 1914)	23.9	IQR=19.2 to 30.1
Māori ethnicity assumed (e.g., te reo Māori language in name)*	5	2.5%
Non-Māori ethnicity (nearly all European/Pākehā)	195	97.5%
Occupational class* (based on occupation at enlistment)		
Highest 3 groupings (i.e., least deprived)	11	5.5%
Middle 3 groupings	81	40.5%
Lowest 3 groupings (i.e., more deprived)	108	54.0%
Military service		
Other war service		
Prior participation in the South African War (1899–1902)	5	2.5%
Subsequent participation in the Second World War (WWII; 1939–1945), albeit not necessarily in an overseas or frontline role	18	9.0%
Military rank on enlistment*		
Commissioned officers (i.e., from officer cadet to field marshal)	4	2.0%
All non-commissioned personnel (excluding the lowest ranks) (i.e., from lance corporal to warrant officer class one)	21	10.5%
The lowest ranks (e.g., gunner, trooper, sapper, signaller, private)	175	87.5%
Timing of frontline service: Year of first arrival at the front line (excluding the n=17 who never went further than the United Kingdom or who worked on hospital ships)		
1914	1	0.55%
1915	40	21.9%
1916	47	25.7%
1917	61	33.3%
1918	34	18.6%
Total to front line	183	91.5%
Mean length of foreign military service (outside of New Zealand)	2.1 years	SD=342 days
Mean length of total military service—including time in New Zealand	2.6 years (965 days)	SD=341 days

Table 1 (continued): Demographic characteristics and military experience of the random selection of 200 male New Zealand military personnel participating in the First World War (for those travelling overseas, who were alive on 1 January 1919, and for whom age at death could be established).

Characteristic	Number	Other data
Theatres of war (with these results not summing to 100% due to participation in multiple theatres by many personnel)		
Any time in France or Belgium	148	74.0%
Any time in Gallipoli/Dardanelles	37	18.5%
Any time in Egypt/Sinai/Palestine	43	21.5%
Any time in Samoa (this was in combination with at least one other theatre—see exclusions in the <i>Methods</i>)	3	1.5%
Only United Kingdom	10	5.0%
Other (e.g., only at sea when away from New Zealand)	2	1.0%

* See the *Methods* in the related study of lifespan in a larger random sample of NZEF personnel.¹⁷
SD = standard deviation; IQR = interquartile range.

Figure 1: New Zealand General Hospital No.1 (Headquarters) Brockenhurst (fracture ward). Qualis Photo Coy (ca. 1915). Auckland War Memorial Museum | Tāmaki Paenga Hira. PH-TECH-925-286 (no copyright).



Table 2: The overall morbidity burden based on diagnoses and hospitalisations during military service (non-fatal injuries and diseases) for the random selection of 200 New Zealand military personnel participating in the First World War.

Characteristic	New condition diagnosed*		Hospitalisation for new condition	
	N	%	N	%
Nil event per person	13	6.5%	22	11.0%
1 per person	58	29.0%	69	34.5%
2 per person	46	23.0%	65	32.5%
3 per person	38	19.0%	25	12.5%
4 per person	25	12.5%	12	6.0%
5+ per person (maximum was 8 for diagnoses, 6 for hospitalisations)	20	10.0%	7	3.5%
	Key number	Other	Key number	Other
Total number	480	240 per 100 cases	358	179 per 100 cases
Mean number	2.40	SD=1.61	1.79	SD=1.21
Median number	2.00	IQR=1.00 to 3.00	2.00	IQR=1.00 to 2.00
Estimated number of events per year of exposure to military service (total service, including training)**	0.92		0.69	

* See Table 3 for these conditions and the *Methods* for how related subsequent diagnoses were excluded.

** Calculated based on the average 2.6 years of military service detailed in Table 1.

e.g., for dysentery/gastroenteritis at 12% and scabies at 5% of personnel. Less common were “trench” diseases (i.e., trench fever, trench foot, trench mouth), and there were no identified cases of typhoid and typhus.

Diagnoses suggestive of post-traumatic stress disorder (PTSD) were present in 10% of the personnel (9.5 cases per 100 personnel). The most common term used was “disordered action of the heart” (DAH), followed by neurasthenia and shell shock.

Due to either injuries or illnesses, most of the personnel were deemed “unfit for military service” by a military medical board (59%) at

some point in their military service (Table 3).

Associations between morbidity and lifespan

The comparisons in Table 4 suggest no statistically significant differences between the various groups. Nevertheless, the pattern was for slightly lower lifespan among those with more diagnosed new conditions, more hospitalisations for new conditions, having had a STI diagnosis and being declared unfit at some point. The exception was for having a mental health diagnosis, which was associated with a slightly higher lifespan (albeit also not statistically significant).

Table 3: The specific non-fatal conditions identified among the random selection of 200 New Zealand military personnel participating in the First World War.

Conditions	Individuals having any occurrence (not including multiple such events)		Cases per 100 people (capturing multiple events per person)
	N	%	
Injuries			
Non-fatal injury event associated with conflict (counting multiple injuries received on one occasion as one injury event; includes chemical warfare injuries; and not counting subsequent sequelae relating to injuries e.g., further complications and operations)	83	41.5%	49.5
Chemical warfare injury (gas poisoning)	12	6.0%	6.0
“Accidental” injuries during military service (e.g., ankle sprain, fall from a horse, from lifting heavy weights)	19	9.5%	9.5
Other injuries	1	0.5%	0.5
All of the above injuries	103	51.5%	59.5
Diseases typically associated with hazardous environmental conditions			
Dysentery/gastroenteritis/“enteritis”/diarrhoeal illness not otherwise specified	23	11.5%	13.0
Scabies	10	5.0%	5.5
Mosquito-borne diseases: malaria, dengue	6	3.0%	3.0
Trench fever (a bacterial infection transmitted by body lice)	5	2.5%	2.5
Trench foot (a condition from prolonged exposure of the feet to cold, damp and often unsanitary conditions)	3	1.5%	1.5
Trench mouth (in modern terminology: acute necrotising ulcerative gingivitis)	2	1.0%	1.0
Other conditions (e.g., trachoma, paratyphoid)	2	1.0%	1.0
All of the above diseases	51	25.5%	26.0
Sexually transmitted infections (STIs)			
Gonorrhoea (one STI only)	16	8.0%	8.0
Syphilis (one STI only)	1	0.5%	0.5
Chancroid/soft chancre (one STI only)	1	0.5%	0.5
Pubic lice (one STI only)	1	0.5%	0.5
“Venereal disease” not otherwise specified (one STI only)	6	3.0%	3.0
Multiple STIs	3	1.5%	3.5
All the above STI categories	28	14.0%	16.0

Table 3 (continued): The specific non-fatal conditions identified among the random selection of 200 New Zealand military personnel participating in the First World War.

Conditions	Individuals having any occurrence (not including multiple such events)		Cases per 100 people (capturing multiple events per person)
	N	%	
Other infectious diseases			
Any respiratory condition (influenza, pneumonia, bronchitis, tuberculosis)	65	32.5%	45.0
Influenza (including pandemic influenza in 1918–1919)	38	19.0%	24.5
Tuberculosis (pulmonary or not stated)	6	3.0%	3.0
Measles, mumps or rubella	16	8.0%	8.5
Fever of unknown origin (“pyrexia of unknown origin” or PUO)	16	8.0%	8.5
Diphtheria	8	4.0%	4.0
Other (not detailed above e.g., extra-pulmonary tuberculosis, “jaundice”—probably infectious hepatitis)	15	7.5%	9.0
All of the above diseases	105	52.5%	66.0
Mental health conditions			
Any form of PTSD (see the Appendix for a full list of terms related to this)	19	9.5%	9.5
“Disordered action of the heart” (DAH)	9	4.5%	4.5
Neurasthenia	6	3.0%	3.0
Shell shock	4	2.0%	2.0
Other mental health conditions (i.e., depression)	1	0.5%	0.5
All of the above conditions	20	10.0%	10.0
Other health conditions			
All other conditions (including some pre-war conditions and others potentially not always directly related to military service e.g., asthma)	69	34.5%	52.0
Musculoskeletal condition (e.g., rheumatism possibly not related to a specific injury)	10	5.0%	6.0
Oral health conditions (excluding trench mouth—see above)	10	5.0%	5.0
Impact of health outcomes on further military service			
Deemed unfit for any further military service at any point during service (albeit in 2 cases the individual subsequently returned to service, 1 re-enlisted for home service, and 1 was assigned base duties)	117	58.5%	58.5
Not deemed unfit for military service	83	41.5%	41.5

Table 4: Lifespan of the veterans in this study in relation to selected morbidity profiles and different exposures during military service.

Characteristic	Mean lifespan of group of interest (years)	Mean lifespan of the rest of the sample (years)	P-value (ANOVA)
Morbidity-related exposures			
3 or more new conditions (n=83) (as per Table 3) vs fewer conditions (n=117)	68.5	70.3	0.3960
3 or more hospitalisations for new conditions (n=44) (as per Table 3) vs fewer hospitalisations (n=156)	67.4	70.2	0.2773
Having any mental health diagnosis (n=20) vs no such diagnosis (n=180)	72.0	69.3	0.4368
Having any STI diagnosis (n=28) vs no such diagnosis (n=172)	65.9	70.2	0.1578
Being declared unfit at some point of service (n=117) vs those never declared unfit (n=83)	69.3	69.9	0.7642
Exposures during military service			
Participating in Gallipoli (n=37) vs any other frontline theatres (n=151)—and excluding those not in such theatres	69.1	70.2	0.6905
Going to the frontline before 1917 (n=88) vs later (n=95)	68.5	70.9	0.2657

Discussion

Main findings and interpretation

The major finding of this work was the very high morbidity burden of this military force—with 94% having at least one new condition diagnosed. The high level of personnel hospitalised (89%) also attests to the relative severity of most conditions, as does the majority (59%) of personnel being deemed no longer fit for further military service at some stage. These high proportions contrast with the official number of personnel wounded or suffering illness as detailed in the *Introduction* (41,317 personnel, equivalent to 39% of all NZEF personnel).

However, our estimate for diagnosed conditions will still be an under-estimate as it will not have captured more minor conditions. For example, nearly all of these personnel probably had a lice infestation³⁵ and many would have had symptom-

atic influenza during the pandemic in 1918–1919²² without it necessarily being recorded in the military files. We also did not count as hospitalisations the admissions to field ambulance units or casualty clearing stations, some of which were for several days, if the soldier returned to the unit.

That infectious disease diagnoses were over twice as common as conflict-related injuries (117 vs 50 cases per 100 personnel respectively) is in contrast to the mortality burden for the NZEF in this war. That is, direct conflict-related deaths were 89% of all deaths compared to 8% dying of “disease”.¹⁸ But in the preceding war involving New Zealand military personnel (the South African War), 59% of deaths were from disease.¹³

Condition severity was sometimes such that injuries were likely to have resulted in life-long disabilities (e.g., for head injuries and amputations). One of the personnel in this study had severe facial injuries that was officially deemed a factor in his suicide soon after the war. Some of the

various infectious diseases listed in Table 3 could also result in adverse long-term sequelae e.g., tuberculosis, syphilis and malaria. Fortunately, there were no cases of typhoid identified in this sample, possibly a reflection of most of these personnel being vaccinated against it. Similarly, there were no cases of typhus, which was a major cause of death in Eastern Europe during this war.⁷

The overall cumulative incidence of STIs in this study (16 cases per 100 personnel) was fairly similar to that estimated previously by an Australian medical historian: at 130 per 1,000 for New Zealand personnel vs 158 per 1,000 for Australian personnel.³⁵ Further work is needed to estimate if such differences by country related to efforts by New Zealand military leadership in STI control, along with the advocacy efforts of Ettie Rout,⁴² which contributed to condom distribution from late 1917.

The finding of 10% of personnel being given a likely PTSD diagnosis is also probably an under-estimate, given how this condition was poorly understood at the time.²⁹ Indeed, a study of Vietnam War veterans in New Zealand reported that 20% had PTSD.⁴³ A more recent study of serving and retired New Zealand military personnel identified 30% with scores indicative of post-traumatic stress.⁴⁴

None of the lifespan results in this study provide statistical evidence of a link with morbidity experiences during the war. But the results were generally in the direction of such an association and so larger studies could consider exploring these issues further. An Australian study of WWI veterans did find statistically significant increased mortality after 1921 for those who were: discharged as medically unfit, discharged as partially/totally permanently disabled and being discharged due to “venereal disease”.⁴⁵

Study strengths and limitations

A strength of this study is that it is the first relatively in-depth analysis of morbidity in a random sample of New Zealand military participants of WWI (to our knowledge). The research benefitted from the individual military records being available online and from the researchers having extensive experience (from previous studies) in interpreting the archival military records of the NZEF, knowledge of the WWI military environment and knowledge of medical terminology. Nevertheless, various limitations with our study need to be considered. In particular:

- Despite involving random sampling,

the study sample was only “fairly representative” of all military personnel in the NZEF given various exclusions. These exclusions are detailed further in the Appendix, but the major ones involved not going overseas to fight, being female, being Pasifika, and not surviving the war. As such it does not reflect the morbidity experience of these particular groups (and indeed, those killed in the war could also have had a worse morbidity profile in the period up until their deaths than other participants).

- We could not account for conditions not detailed in the military files. This under-recording was probably common, especially for more minor conditions that did not involve treatment by medical personnel (e.g., lice infestation and milder cases of pandemic influenza as discussed above). Indeed, one New Zealand soldier contributed a satirical poem to the “Chronicles of the N.Z.E.F” about the how wounded men were entitled to wear a gold stripe on the left sleeve, yet there was no formal recognition for “little ills” like “dysent’ry”, fever, septic sores, shell shock, frost-bite, rotting feet and being gassed.⁴⁶ Also, some conditions may not have been self-reported (e.g., symptoms of a STI) given the punitive approaches that could be taken by the military authorities.²⁵ Similarly, such “sensitive” diagnoses relating to STIs or mental health may have not been recorded by staff on purpose, so as to protect the reputation and future career of the patient. Finally, dental records were relatively sparse in the individual military files, suggestive that such records were held separately.
- There was a lack of specificity to some of the conditions as shown by the “pyrexia of unknown origin” category in Table 3. Such fever symptoms could have potentially arisen from many different infectious diseases.
- We may have missed some relevant data due to misinterpreting the hand-written text/acronyms/abbreviations in the archival military files. This is because of the highly cursive handwriting styles typically used and due to the complexity of some of the records (e.g., one was 189 pages long, and some were mixed up with WWII records). Nevertheless, the inter-observer assessment study suggested reasonable results for

sensitivity and specificity to the extent these can be estimated. Indeed, the values (such as 84% for the lowest end of the sensitivity range) might be under-estimates since the first author also did subsequent logic checks on the entire dataset and identified additional data items that could then be included in the final dataset version.

Possible lessons for governments and further research possibilities

It has taken over 100 years for the morbidity burden for WWI personnel to be established in terms of new conditions and hospitalisations for new conditions. This highlights the need for governments to properly document such health burdens from past wars. Such documentation could better inform the need for conflict prevention (e.g., via diplomacy) as well as for ongoing maintenance of high health status among serving military personnel, provisioning them with appropriate equipment and ensuring high-quality

medical services to protect and treat them.

Further research could be done, including studies that explore the relationship between health conditions and the proximity to frontline combat in various theatres of WWI. Similarly for health risks associated with different roles in the military (e.g., being a health worker, being a private or officer, etc.) and for cross-country comparisons (e.g., New Zealand vs Australian military personnel). Māori or Pasifika researchers could also be funded to study the health burden in a random sample of these ethnic groups of military personnel.

Conclusions

The overall morbidity burden of this military force in WWI was very high, and much higher than the previous official estimates. A wide range of conditions were found in this study, but as with preceding conflicts the cases of infectious diseases were more frequent than those from conflict-related injuries.

COMPETING INTERESTS

None declared.

ACKNOWLEDGEMENTS

The authors thank Christine Clement (genealogist) for assistance with determining the dates of birth and death for this cohort. Auckland War Memorial Museum kindly provided a copy of the Cenotaph records that assisted with sampling.

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Appendix: Additional methods and acronyms, abbreviations and terms list used in this study

Additional methods—sample selection

The sample was derived from a previous study on NZEF participants in WWI.¹ In summary, this former work involved the following steps:

- In February 2021, data were downloaded on all NZEF participants in WWI from the Auckland War Memorial Museum's Cenotaph website database.² This was 104,993 individual names, which was 99.1% of war participants according to an official estimate of 105,986.³
- Within this dataset we randomly selected a 5% sample of personnel (the random number generator in Microsoft Excel was used for all randomisation processes). From this sample the following were then excluded:
 - a. Non-veterans (defined as those dying in the war and subsequent weeks up to 31 December 1918), with this group being 18.2% of the sample.
 - b. Female participants (who were nurses and volunteers), with this being 0.47% of the sample.
 - c. Pasifika military personnel who came from South Pacific Islands to join the NZEF, with this group being 0.50% of the sample. This grouping was excluded given the focus of this former study was on veterans from New Zealand and because there is large heterogeneity in backgrounds for Pasifika populations (in demography and culture).
- Then, given the focus of the previous study being on NZEF veterans exposed to war overseas, a random subset of 1,000 personnel were further examined to exclude the following:
 - a. Being a non-veteran (as per the definition above) on closer examination of the records.
 - b. Not seeing active war service overseas (e.g., not actually leaving New Zealand, deserting on route or being deemed medically unfit prior to war exposure).
 - c. Only serving in Samoa (since this theatre of the war involved no conflict with Germany).
 - d. Being part of a non-New Zealand military force (e.g., the Australian Imperial Force

(AIF), or the Royal Navy of the United Kingdom [UK]).

The above process left 887 personnel in the sample out of the subsample of 1,000. Of these, the age at death could be ascertained from archival sources in 96.6% (857/887). Then, out of this group of 857 personnel with lifespan data (to ensure that they survived the war), we randomly selected 200 personnel for the in-depth analysis of their morbidity experience.

Exclusions from the sample

In 14 cases (7.0%) the selected individuals in the sample of 200 had to be excluded. These included those subsequently found on close examination to be ineligible for inclusion (i.e., only went to Samoa [n=1]; participated in another military force [n=1]; the military file was completely missing [n=2], or because a section of the military file was missing [n=10]). These individuals were then replaced with others from the sub-sample of 857 personnel to remake up the 200 sample for this morbidity study.

Acronyms, abbreviations and terms (of potential relevance to future researchers)

The following acronyms, abbreviations and terms were derived from a range of sources, including:

- Official New Zealand sources: <https://nzhistory.govt.nz/war/ww1-abbreviations-acronyms> and <https://natlib.govt.nz/researchers/guides/first-world-war-medical-services/>
- A New Zealand genealogical resource: <https://freepages.rootsweb.com/~sooty/genealogy/ww1abbreviations.html>;
- A UK source: <https://www.longlongtrail.co.uk/soldiers/a-soldiers-life-1914-1918/common-british-army-acronyms-and-abbreviations-of-the-first-world-war/>.

List of acronyms, abbreviations and terms

- 1AAH = 1st Australian Auxiliary Hospital, Luna Park, Cairo
- 1AGH = 1st Australian General Hospital
- 2nd Australian Depot Weymouth; used for convalescence; available from <https://birtwistlewiki.com.au/wiki/Weymouth>

- AFB = Army Form B
- AS = “Active Service”
- A/H = Admitted hospital
- Abbasich = Canadian Stationary Hospital, Alexandria
- Abbassia = Hospital, Cairo
- Ad Hosp or “Adm Hosp” = for admission to hospital.
- AGH = Australian General Hospital
- Alder Hay = Liverpool Orthopaedic Centre, Liverpool
- Amb = Field ambulance
- Ampt or Amp = Amputation
- Aotea Home/House = a convalescent facility in Heliopolis, Cairo, Egypt (not classified as a hospital in this current study); available from <https://natlib.govt.nz/records/22564172>
- Aquitania = a hospital ship
- ASH = Australian Stationary Hospital
- Aus CCS = Australian Casualty Clearing Station
- Balmer Lawn = A part of No.1 New Zealand General Hospital (Brockenhurst)
- BRC = British Red Cross
- BRCH = British Red Cross Hospital
- Bright’s disease (also just “Bright”); in modern terms this is acute or chronic nephritis (a kidney disease)
- Brighton = New Zealand officers and nurses convalescent homes
- B’hurst = see Brockenhurst
- Brock = see Brockenhurst
- Brockenhurst = No.1 New Zealand General Hospital (Hampshire, England)
- BW = Bullet wound
- C/F = Compound fracture
- Can CCS = Canadian Casualty Clearing Station
- Can GH = Canadian General Hospital
- Can Stat Hosp = Canadian Stationary Hospital
- Cas = Casualty
- Cashmere Military Sanatorium, Christchurch = New Zealand military hospitals and convalescent homes
- CCH = Casualty clearing hospital
- CCS = Casualty clearing station
- Classified A (disabled officer or nurse) = Fit for general service
- Classified A1 = Fit for active service
- Classified B (disabled officer) = Fit for service in a garrison or labour unit abroad
- Classified B1 = Able to be made fit by medical treatment
- Classified C (disabled officer or nurse) = Fit for home service: (i) active duty with troops
- Classified C (disabled officer or nurse) = Fit for home service: (ii) sedentary employment only
- Classified C1 = Likely to become fit for service overseas after special training
- Classified C2 = Permanently unfit for active service but fit for service in New Zealand
- Classified D = Permanently unfit
- Classified D (disabled officer or nurse) = For admission to a command depot
- Classified E (disabled officer) = Requiring indoor hospital treatment: (i) in an officers military of auxiliary convalescent hospital
- Classified E (disabled officer) = Requiring indoor hospital treatment: (ii) in an officers hospital
- Classified F (disabled officer or nurse) = Permanently unfit for any further military service
- Consumption = an archaic name for tuberculosis
- Coy = Company
- CPDI = Chronic-Pulmonary Disease, Indeterminate
- CPT = Chronic pulmonary tuberculosis
- CSM = Cerebrospinal meningitis
- DAH = Disorderly action of the heart; this was also sometimes called “effort syndrome” or “soldier’s heart”; often the result of stress or fatigue, it does not imply there was any organic disease; available from <https://www.longlongtrail.co.uk/what-were-vdh-and-dah/>
- Dang ill = On dangerously ill list
- DAS = Died at sea
- DDS = Defence Dental Service
- DI = Dangerously ill (e.g., placed on dangerously ill list)
- DOD = Died of disease
- DOI = Died of illness
- DOW = Died of wounds
- DRS = Divisional rest station
- EGH = Egyptian General Hospital
- Endell St = Endell Street Military Hospital, London
- Fd/Fld Amb = Field ambulance
- FA = Field ambulance
- Fargo = “Fargo Military Hospital” at Larkhill on Salisbury Plain
- Forest Park = A part of No.1 New Zealand General Hospital (Brockenhurst)
- Gas hysteria and “gas neurosis” = Anxiety during a gas attack⁴

- Gen/Genl H or GH = General hospital
- Gezirah = Anglo American Hospital, Cairo
- Ghajn Tuffieha = Convalescent camp, Malta
- Ghizel = Red Cross Hospital, Cairo
- GSW = Gunshot wound
- GSW RWU = Gunshot wound, remaining with unit
- H'church/Hch = New Zealand convalescent hospital (Hornchurch) in London, England
- Heliopolis = Heliopolis Palace: 1st Australian General Hospital, Egypt (see Aotea, a convalescent home also at Heliopolis)
- Helouan = Convalescent hospital, Egypt
- Hornchurch = New Zealand convalescent hospital (London)
- Hos = Hospital
- HS = Hospital ship
- ICT = Inflammation of the connective tissue
- IDK = Internal derangement of the knee
- Isol Hosp = Isolation hospital
- Isolation H = Isolation hospital
- Kantara = the 24 Stat Hospital Kantara Egypt
- KIA = Killed in action
- King George V Hospital, Rotorua = New Zealand military hospitals and convalescent homes
- Lady Godley's = Convalescent hospital, Egypt
- M I Hospital = Military infectious hospital
- M/U = Medically unfit
- Maheno = A hospital ship (New Zealand)
- Manor Hospital, Epsom = Epsom, Surrey; from 1916 became Manor War Hospital
- Marama = A hospital ship (New Zealand)
- MB or Med/B = Medical board
- MDS = Main dressing station
- Mental = a mental health condition
- MG = Machine gun
- MGB = Machine gun bullet
- MH Tidworth = Tidworth Military Hospital (in the UK)
- Mt Felix = NZEF Hospital, near 2nd General Hospital, Walton-on-Thames
- Mudros/Moudros = a port on the island of Lemnos, Greece
- NYD = Not yet diagnosed
- NYDN = Not yet diagnosed
- NZ Con Depot = New Zealand convalescent depot
- NZ Con Hom = New Zealand convalescent home
- NZGH = New Zealand General Hospital
- NZGH Brockenhurst = No.1 New Zealand General Hospital, Brockenhurst, England
- NZGH Codford = No.3 New Zealand General Hospital, Codford, England
- NZGH W on T = No.2 New Zealand General Hospital, Walton-on-Thames, England
- NZHS = New Zealand hospital ship
- P de K = New Zealand General Hospital, Pont de Koubbeh, Cairo; later 2nd New Zealand Stationary Hospital
- P/U or PU = Permanently or physically unfit
- Phthisis = an archaic term for any disease that causes wasting of the body, especially pulmonary tuberculosis; in this study it is generally assumed to be pulmonary tuberculosis
- PIE = Proximity to the battle, Immediacy of treatment and Expectancy of recovery, including return to duty⁵
- Pnt de K = New Zealand General Hospital, Pont de Koubbeh, Cairo; later 2nd New Zealand Stationary Hospital
- Pont de Koubbeh/Kubb = New Zealand General Hospital, Pont de Koubbeh, Cairo; later 2nd New Zealand Stationary Hospital
- Post-concussion syndrome (PCS) and post-concussional disorder (PCD)
- POW = Prisoner of war
- PTB = Pulmonary tuberculosis
- PTSD = Post-traumatic stress disorder (see terms for "shell shock" and DAH)
- PUO = Pyrexia (fever) of unknown origin (described in the UK context as "*medical term usually applied to Trench Fever*")
- Queen Mary Hospital = Hanmer Springs, New Zealand; used for rehabilitation for mental and nervous conditions, particularly shell-shock
- Ramleh = Hospital, Alexandria, Egypt
- RAP = Regimental aid post
- Ras El Tin = Military hospital, Alexandria, Egypt
- Rotorua = May refer to King George V Military Hospital in Rotorua
- Rouen = New Zealand embarkation camp and hospital, Rouen
- Salah El Din (Saladin) = Citadel Hospital, Cairo
- Scabies = a mite infestation that could result in hospitalisation
- SC = soft chancre (an STI; the modern term is chancroid)
- Segregation = Isolation (for infectious disease)
- Ser ill = On seriously ill list
- SH or Stat Hos or Sty or Sty H = Stationary hospital

- Shell shock synonyms; Wikipedia gives these other terms for “shell shock”: “Bullet wind”, “soldier’s heart”, “battle fatigue”, “operational exhaustion”. Wikipedia gives these other terms for “Da Costa’s syndrome” (another outdated term): “soldier’s heart”, “cardiac neurosis”, “chronic asthenia”, “effort syndrome”, “functional cardiovascular disease”, “neurocirculatory asthenia”, “primary neurasthenia”, “subacute asthenia” and “irritable heart”. Wikipedia also details combat stress reaction: also known as “combat fatigue”, “battle fatigue”, or “battle neurosis”. Words used in the text by Carbery: concussion neurasthenia, psychasthenia, hysteria or neurasthenia (in: <http://nzetc.victoria.ac.nz/tm/scholarly/tei-WH1-Medi-t1-g1-t1-body-d14.html#n353>). Also by Carbery: “Mental States”; see also “DAH” in this glossary. Terms from Horrocks:⁶ nervous conditions variously described as “shell shock”, concussion neurasthenia, hysteria, exhaustion, pithiatism, and psychasthenia. Other possible terms include: “combat stress reaction” (CSR), “war neurosis”, “war strain” and “battle fatigue”.
- Shoubra = Infectious diseases hospital, Shoubra, near Cairo
- SI = Seriously ill (Placed on SI list)
- SI List = Seriously ill list
- SIW = Self-inflicted wound
- Soft sore = Chancroid, a sexually transmitted infection
- SOS or Str off str = Struck off strength (although this might not necessarily be health related): “*A soldier no longer capable of active service is removed from the list of soldiers available for serving at the front*”
- Southwark = Southwark Military Hospital, East Dulwich, Greater London
- SW = Shrapnel wound
- TAT = Temporary ambulance train
- TB = an abbreviation for tuberculosis, but in some contexts it may be “Temporary Base (medical)”
- Trench fever = a bacterial disease (*Bartonella quintana*) transmitted by body lice; also known as “five-day fever”, “quintan fever”
- Trench foot/feet = a condition resulting from prolonged wet feet; it could result in hospitalisation, amputations and death
- Trench mouth = In modern day terms it is “acute necrotizing ulcerative gingivitis” (ANUG), a mixed bacterial condition; in the WWI context it was probably related to poor living conditions, malnutrition, smoking and extreme psychological stress; see also Vincent’s gingivitis in this glossary
- TU = Temporarily unfit
- VD = Venereal disease (in modern terminology: “sexually transmitted infection”) e.g., gonorrhoea or syphilis
- VD Section = Venereal disease section (attached 3rd New Zealand General Hospital, Codford)
- VD Ward = Venereal disease ward
- VDC = Venereal disease, chancre (modern term is chancroid)
- VDG = Venereal disease, gonorrhoea
- VDH = Valvular disease of the heart
- VDS = Venereal disease, syphilis
- VDSC = Venereal disease, soft chancre (modern term is chancroid)
- Ven Hosp = Venereal disease hospital
- Ven Section = Venereal disease section (attached 3rd New Zealand General Hospital, Codford)
- Vincent’s angina = an archaic term for pharyngitis and tonsillitis together
- Vincent’s gingivitis = an archaic term for necrotising ulcerative gingivitis; see “trench mouth” in this glossary
- W RWU = Wounded, remaining with unit
- Walton/Walton-on-Thames = No.2 New Zealand General Hospital, Walton-on-Thames, England
- Whitlow = an infection of the finger and especially the fingertip that is typically caused by infection of a virus (such as the herpes simplex virus)
- WIA = Wounded in action
- Wnd = Wound or wounded
- Woodcote Park = Military convalescent hospital, Epsom, Surrey (in use in 1915)
- WWCS = Walking wounded collecting station

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