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# A nutritional analysis of New Zealand military food rations at Gallipoli in 1915: likely contribution to scurvy and other nutrient deficiency disorders

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**Abstract**

**Background** Amongst New Zealand soldiers in Gallipoli in 1915 there were reports of poor food quality and cases of scurvy. But no modern analysis of the military food rations has ever been conducted to better understand potential nutritional problems in this group.

**Methods** We analysed the foods in the military rations for 1915 using food composition data on the closest equivalents for modern foods. We compared these results with other plausible diets and various optimised ones using linear programming.

**Results** Historical accounts provide evidence for poor food quality supplied to these soldiers. The nutrient analysis suggested that the military rations were below modern requirements for vitamins A, C and E; potassium; selenium; and dietary fibre. If military planners had used modest amounts of the canned vegetables and fruit available in 1915, this would probably have eliminated four of these six deficits. The results from the uncertainty analyses for vitamin C (e.g., 95% uncertainty interval [UI]: 5.5 to 6.7 mg per day), was compatible with the range known to cause scurvy, but the UI for vitamin A intake was only partly in the range for causing night blindness. To indicate the gap with the ideal, an optimised diet (using foods available in 1915), could have achieved all nutrient requirements for under half the estimated purchase cost of the 1915 military rations.

**Conclusions** There is now both historical and analytic evidence that the military rations provided to these soldiers were nutritionally inadequate in vitamin C, and probably other nutrients such as vitamin A. These deficits are likely to have caused cases of scurvy and may have contributed to the high rates of other illnesses experienced at Gallipoli. Such problems could have been readily prevented by providing rations that included some canned fruit or vegetables (e.g., as manufactured by New Zealand at the time).

The upcoming centenary events concerning World War One (WWI) provide an opportunity to consider the historical lessons from this conflict—including those related to nutrition and military planning. Part of this conflict involved the New Zealand Expeditionary Force in a multi-country campaign on the Gallipoli Peninsula in Turkey. This campaign ran from April 1915 to January 1916, at which time a withdrawal from the peninsula occurred.[1] There were an estimated 7991 casualties (57% of the NZ military personnel) and 2779 died.[2 (p275–378)] At least 200 of the deaths were from infectious diseases such as dysentery and typhoid.[2 (p263)]

In addition, the official New Zealand medical history of WWI refers to reports of scurvy among the troops (in three places in the report[3 (p66, 106, 123)]). Furthermore, as Christopher Pugsley notes in his seminal account of New Zealanders at Gallipoli,[1 (p346)] most of these soldiers ended the campaign too sick and too weak to continue soldiering.

The importance of feeding an army properly has long been recognised as critical to its functioning. As Napoleon Bonaparte acknowledged: an army really does march on its stomach.[4 (p274)] Yet it is well known that military personnel have often suffered from nutritional deficiencies.

For example, in the American Civil War, scurvy was diagnosed in 47,000 Union troops and "…by physicians in the field from all theatres of action throughout the war".[5] Such cases of scurvy were often successfully treated with the provision of fresh vegetables. Scurvy was a major problem for both armies in the Crimean War[5] and there was evidence for it in a number of other historical military settings such as Chinese garrisons and US military outposts.[6]

Evidence of vitamin A deficiency (reports of "night blindness") was also reported for American Civil War troops on both sides and especially during the last year of the war.[5] Other work considered night blindness in an Austrian naval crew in 1857-59, which was successfully treated with the provision of ox liver.[7] Similarly, in 1863, night blind soldiers in a Paris garrison were successfully treated with cod-liver oil.[7]

Given this background, we examined historical accounts and performed a retrospective analysis of military rations provided to the New Zealand troops involved in the Gallipoli campaign in 1915.

## Methods

**Historical context—**To provide context for food supply and consumption by military personnel in Gallipoli, we examined a number of documents written by contemporary authors,[3 8-10] and by subsequent historians and researchers[1 2 5 11-13] (including one of us[14]).

**Scenario development—**Table 1 details the specific scenarios we considered which included replicating the actual military food rations as best as possible (Scenario "R-A") but also to describe three possible alternatives. These were: (i) to slightly improve the amount of food variety in the 1915 rations by providing less corned beef and more fruit and vegetables (Scenario "R-V"); (ii) to achieve modern nutritional recommendations for the lowest cost (optimised dietary pattern, Scenario "R-O"); and (iii) to perform the latter but with more food variety (Scenario "R-OV").

We suggest that it is very plausible that increased food variety and access to more vegetables and some fruit would have been desired by the soldiers (Scenario R-V), and that military planners could have considered this given prior evidence for problems with scurvy in the American Civil War, Crimean War and other preceding military situations (see Introduction). Nevertheless, it is acknowledged that the more optimised scenarios (R-O and R-OV) are completely hypothetical given the limitations of nutritional science in 1915.

In Table A1 (see Appendix 1) we list the actual rations as used by the New Zealand Expeditionary Force and documented on 13 April 1915.[3 (p543)] The "nearest equivalent" modern foods used in the various scenarios are detailed in Tables A2 and A3.

**Nutrient requirements and data used—**For the scenarios involving optimisation of nutrients (R-O and R-OV in Table 1) we generally used the modern day "estimated average requirements" (EARs) of nutrients per day for adult men which are based on values set for Australia and New Zealand.[15] But we also considered current nutrient intakes for men from the New Zealand Adult Nutrition Survey (NZANS).[16] Further details are provided in Table 3. For food composition data we used the 2012 "New Zealand food composition database" (http://www.foodcomposition.co.nz/foodfiles).

**Food prices—**To estimate the likely costs of the different scenarios, we used current 2011/12 food prices. These came from the official food price index (average monthly data for New Zealand in 2011)[17] or when not available, supermarket prices (as detailed in Tables A2 and A3 in the Appendix 1).

**Approach to mathematical modelling and uncertainty—**For the nutrient optimisation we used the simplex algorithm to solve this linear programming problem (see Briend et al[18] for a detailed description of the latter). The scenarios were modelled in Microsoft Excel 2010 (Excel Solver, Simplex method). Details of the uncertainty analysis are in the Appendix 1.

### Table 1: Specific nutritional scenarios used for the analyses of the actual military rations of 1915 and alternatives

| Name and aim of specific scenario | Additional details |
|---|---|
| Scenario "R-A": To replicate the actual military food rations | We used the nearest-equivalent modern foods, see Table A2 for further details of these rations. The modern food nearest equivalents we used are detailed in Table A3. |
| Scenario "R-V": To slightly improve variety of the 1915 rations | In this Scenario we simulated a better attempt by the planners of military rations to approximate the typical NZ diet at the time i.e., more vegetables and fruit. So we halved the amount of corned beef (down to 227 g) and added:<br>1 cup each of the two cheapest canned vegetables (tomatoes [240 g], and peas [248 g] – both canned products were available in 1915, see Table A3 in the Appendix 1).<br>1 cup of the cheapest canned fruit (apricots with syrup [240 g], also available in 1915). |
| Scenario "R-O": To achieve modern nutritional recommendations for the lowest cost (optimised dietary pattern) | To achieve this optimised diet with the type of dried and canned foods available at the time, while also: (i) achieving the same level of dietary energy as Scenario R-A; (ii) to ignore the modern recommendations on sodium levels (given the food preservation value of high sodium levels in a military field setting). See text and Table 3 for further details on the specific nutrient recommendations. |
| Scenario "R-OV": As for Scenario "R-O" but with more variety | As for Scenario R-O above but with progressively lowering the maximum amount of the highest individual food item (by weight) until the variety in the original ration increased the number of foods reaching over 50 g per day to up to 10 different foods. |

## Results

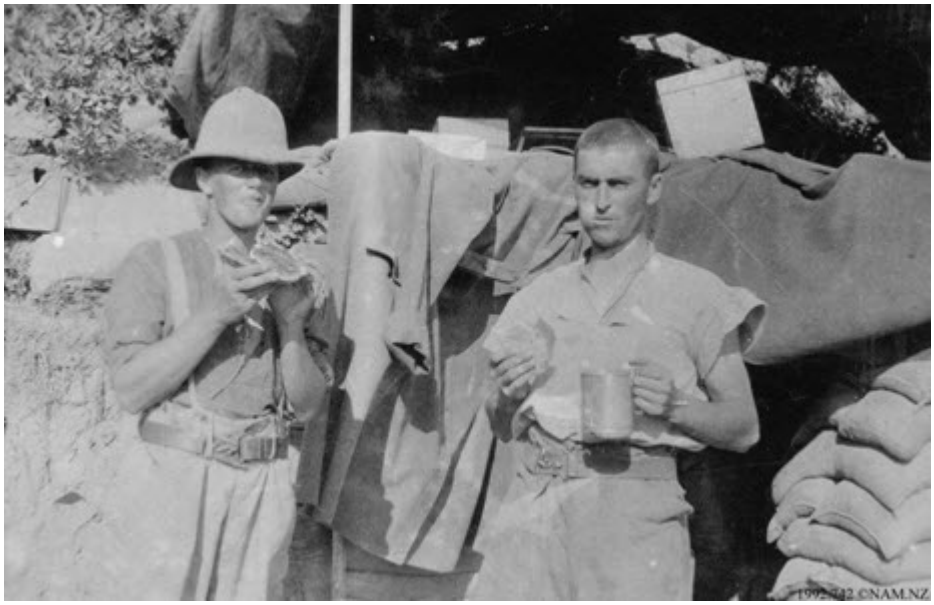
**Historical reports of food issues—**That the majority of meals on Gallipoli consisted of corned beef (bully beef), hard biscuits and tea is especially significant to this study. For example, the first New Zealand historian of the campaign, Major Fred Waite, noted:

> Food was always plentiful (except just after the Great Blizzard in November when stocks ran very low). Tinned meat, jam and hard biscuits and a mug of tea provided 99 per cent of the meals[10 (p161)] (see Figure 1).

On occasion (e.g., near the end of campaign[2 (p267)]) there were some improvements in the food provisioning. As one soldier remarked:

> We get very well fed here, considering, but we do miss the fresh vegetables and fruit. We get plenty of rice, tea, sugar, biscuits and bully beef, jam, onions etc and an adequate supply of milk [tinned condensed] and bread. Once or twice we have had an egg each, and yesterday actually had a little fresh mutton served out.[14 (p202)]

**Figure 1. Two signallers outside the Divisional Signal Office on the Gallipoli Peninsula (1915) enjoy a meal of bread and jam, washed down with a mug of tea. (The jam did provide a source of Vitamin C but it was not enough.)**



**Source:** Used with permission from National Army Museum, New Zealand (Number: 1992.742)

An impression of some of the difficulties with food and water supply for the New Zealand military in Gallipoli is suggested by these commentators:

> After the first two days the battalion had a quiet time in the Walker's Ridge position. One of the greatest difficulties was in bringing up ammunition, water and food. The track up to the hill, 500 feet above the beach, was very narrow and steep, and exposed to sniping fire from the Turkish trenches; only small loads could be carried by each man, and each trip took a long time.[8]

> With all these discomforts, the exhaustion of labour, the strain of unceasing vigil and shell fire, the lack of nourishing food, and little sleep, there was always a shortage of water and the possibility of no water at all. One pint of water a day was the usual issue[9 (p38)] (see Figure 2).

Other conditions may have limited food intake and palatability:

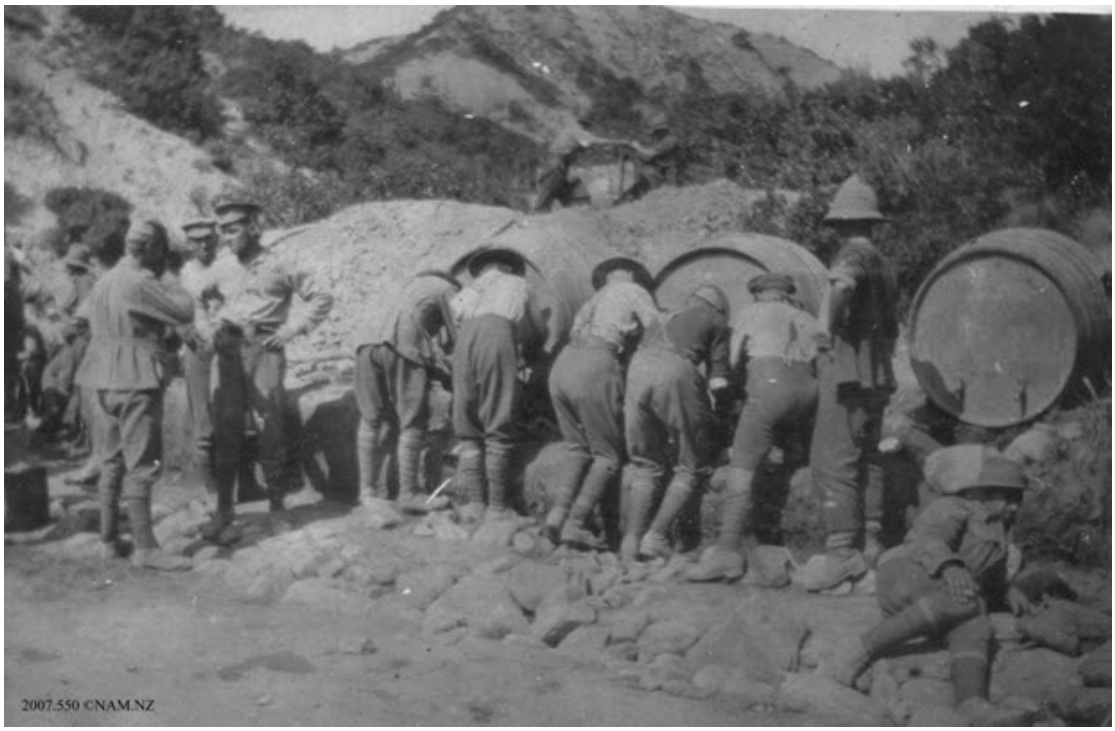
> Owing to the annoyance of the flies some sections did not eat anything but a dry biscuit during the daytime. To eat biscuit and jam in the daytime a man had to keep moving the hand that held the food.[9 (p37)]

> …. however palatable in a temperate climate, any form of tinned food becomes distasteful in a semi-tropical summer unless ice is available. … Not only was the clothing inadequate but the food and the feeding of the troops was unsatisfactory.[3 (p113)]

In commenting mainly on sanitation, the difficult circumstances for food preparation were described:

> It is questionable whether any alterations in the dietary – and some were made – could have improved the sanitary situation. The baneful system of individual cooking, then prevalent, would have ruined any ration however good; every man cooked for himself, every dug-out became a midden of fly contaminated food and food refuse.[3 (p114)]

**Figure 2. A precious water point at Anzac Cove, Gallipoli Peninsula (1915). Two quarts a day was the normal ration for New Zealand soldiers and it had to be used for all purposes. Most went to make tea. As one New Zealand soldier wrote: 'water is worth its weight in gold here'.**




**Source:** Used with permission from National Army Museum, New Zealand (Number: 2007.550)

Finally, Carbery[3 (p113)] appears to support a quote in the final report of the Dardanelles Commission, which stated that: "there was nothing actively injurious to health in the meat; but it was of poor quality, and, from being salt and stringy, it caused some intestinal irritation and so conduced to diarrhoea".

The bulk of the food diet of the New Zealanders at Gallipoli was supplied via the United Kingdom through its Army Service Corps. Generally it was inferior in quality to similar food that originated from New Zealand. Most of the corned beef was supplied from Argentina and Fred Waite commented that it's poor quality and the fact that it was served for meals three times a day, "becomes more than the constitution of a New Zealander can stand".[10 (p163)]

When limited sources of food from New Zealand did arrive in at Gallipoli with the latest batch of Reinforcement drafts, it was much sought after and highly prized. This was especially true of the New Zealand army biscuit which was white, easy to eat and pleasant tasting. In contrast, British army biscuits were hard "beyond belief". New Zealand soldiers at Gallipoli tended to nibble the edges of these hard slabs and throw their centres into No Man's Land.[10 (p162)]

**Nutritional analyses—**The calculated weights of the foods in the different scenarios are shown in Table 2 and the nutrient analysis in Table 3. Of note is that the military rations (Scenario R-A) were far below modern nutritional requirements for vitamin C intake, around a third of the current estimated average requirement (EAR). They were also below the EARs for: vitamin A (33% too low), vitamin E (11% too low), potassium (36% too low), selenium (20% too low) and dietary fibre (36% too low), (Table 3).

Relative to modern requirements, the military diet was also excessively high in saturated fat (3.1 times too high) and sodium (5.2 times higher than the 2300 mg upper limit) (Table 3).

If the planners of military rations had made these rations somewhat more like the typical New Zealand diet in terms of modest amounts of vegetables and fruit (i.e., one cup each per day of peas, tomatoes and apricots used in our "Scenario R-V"), then this would have substantially improved the nutrient quality. In particular it would have eliminated the below EAR intakes of vitamins A, C and E and dietary fibre; improved intake of potassium, but would have made little change to selenium intake. It would also have partly reduced the high intakes of saturated fat and sodium, which is desirable from a health perspective.

If the *relative* food prices are roughly equivalent between now and 1915, then this alternative ration would have been achieved with only a minor increase in cost above the original ration (NZ$ 11.43 per day vs 11.03, Table 3). However, the higher weight (an extra 501 g/day) would have increased transport costs (Table 2).

In 1915 there was no possibility that a properly "optimised diet" could be developed as there was limited knowledge of nutrition and no capacity to apply mathematical techniques such as linear programming. Nevertheless, it is plausible that military planners could have made moderately more use of a variety of canned and dried foods that were available in New Zealand in 1915 and produced in other developed countries.

It is also of interest to demonstrate how far modern knowledge and methods can allow for optimal military rations to be formulated. Hence we "optimised" the military rations using canned and dried foods available in 1915, and found that only six foods would technically be required to meet all nutritional requirements: bread, flour, cheese, rolled oats, dried peas and canned tomatoes (Scenario R-O in Tables 2 and 3). Indeed, this ration would have been healthier in all of the dimensions shown in Table 3. Furthermore, this ration would have cost under half the cost of the original ration and would be a similar weight.

Expanding the variety of this optimised ration to include ten items (over 50 g each) as per Scenario R-OV would have probably resulted in additional cost compared to Scenario R-O. But this cost was still estimated to be likely to below that of the original ration (i.e., $9.54 vs $11.03 per day). However, the extra weight of the food (466 g/day) would have increased transport costs (Table 2).

The results in Table A3 (see Appendix 1) indicate that cheese was the likely major contributor to vitamin A intake in the rations. For vitamin C it was either jam, followed by dried potatoes (using the USDA food composition data); or corned beef followed by jam (using NZ food composition data).

In the uncertainty analysis (Table 5) the mean vitamin A intake was below half the EAR of 625 mcg and the 95% uncertainty interval (UI) never approached this requirement (using both food composition datasets). Similarly, for vitamin C intake with the mean below a quarter of the EAR and the upper limit of the 95%UI never exceeding a third of the EAR.

**Table 2. Foods (with weights in g/day) included in the various daily dietary scenarios with some of these (in Scenarios R-O and R-OV) selected automatically in the optimisation process**

| Food items | Scenario R-A (actual) | Scenario R-V (extra variety) | Optimised diets | |
|---|---|---|---|---|
| | | | Scenario R-O | Scenario R-OV |
| **Food in the military rations of 1915 (descending amounts)** | | | | |
| Corned beef (canned) | 454 | 227 | 0 | 0 |
| Alternatives: Bread (white) | 187 | 187 | 330 | 225 |
| Or biscuit | 150 | 150 | 0 | 225 |
| Or flour (white) | 150 | 150 | 585 | 225 |
| Bacon | 113 | 113 | 0 | 29 |
| Cheese (cheddar) | 85 | 85 | 110 | 82 |
| Jam | 85 | 85 | 0 | 0 |
| Sugar (white) | 85 | 85 | 0 | 0 |
| Alternatives: | | | | |
| Dried peas | 19 | 19 | 8 | 0 |
| Or dried beans | 19 | 19 | 0 | 225 |
| Or dried potatoes | 19 | 19 | 0 | 0 |
| Salt | 14 | 14 | 0 | 0 |
| Mustard | 1.4 | 1.4 | 0 | 0 |
| Pepper | 0.8 | 0.8 | 0 | 0 |
| **Additional foods that could have been used in 1915 (see Appendix 1)** | | | | |
| Peas (canned) | – | 248 | 0 | 0 |
| Apricots (canned) | – | 240 | 0 | 107 |
| Tomatoes (canned) | – | 240 | 353 | 225 |
| Oats (rolled) | – | 0 | 337 | 225 |
| Peaches (canned) | – | 0 | 0 | 225 |
| Fish (canned) | – | 0 | 0 | 56 |
| Other** | – | 0 | 0 | 0 |
| **Total food weight g/day** | **1382** | **1883** | **1724** | **1848** |
| **Total foods ≥ 50 g (N)** | **6*** | **11** | **5** | **10** |
| **Total types of food (N)** | **14** | **17** | **6** | **11** |

**Notes:**

* Six foods when considering the bread, biscuits and flour were describes as alternatives; and similarly for peas, beans or potatoes (see Table A1).

** Includes other canned food: pears, beans, sheep meat and milk powder.

## Table 3. Results of estimated daily nutrient intakes for the various scenarios (replicated "actual" and more optimal daily diets)

| Nutrients | EARs or other target values used as constraints in the optimisation modelling ([RDI] – for comparison) | Scenario R-A ("actual") | Scenario R-V (extra variety) | Optimised diets | |
|---|---|---|---|---|---|
| | | | | Scenario R-O | Scenario R-OV |
| Price (NZ$ in 2011/12) | Not relevant | 11.03 | 11.43 | 5.16 | 9.54 |
| **Macronutrients** | | | | | |
| Energy (kJ) | As per Scenario R-A* (except for R-V) | 18,213 | 17,087 | 18,213 | 18,213 |
| Protein, total (g) | ≥52 [64] | 193.0 | 157.0 | 160.6 | 185.3 |
| Polyunsaturated fatty acids (g), (current intake in men from the NZANS**) | 13.1 g (contributing 4.8% of dietary energy in modern NZ men) | 9.6 | 8.4 | 13.1 | 13.1 |
| Saturated fatty acids (g) | Using an upper limit of 12% of typical energy intake (i.e, 27.5 g for an intake of 11,450 kJ) | 85.5 | 61.8 | 27.5 | 27.5 |
| Sugars (g) | No limit | 160.8 | 239.4 | 26.8 | 110.4 |
| Dietary fibre (g) | ≥30 (AI) | 19.1 | 36.9 | 66.8 | 88.5 |
| **Micronutrients** | | | | | |
| Calcium (mg) | ≥840 [1000] | 976 | 1,100 | 1,678 | 1,619 |
| Iron (mg) | ≥6 [8] | 20.8 | 23.4 | 40.9 | 45.2 |
| Potassium (mg) | ≥3800 (AI) | 2,434 | 3,414 | 3,800 | 6,024 |
| Selenium (mcg) | ≥60 [70] | 48.0 | 48.6 | 60.0 | 87.4 |
| Sodium (mg) | Upper limit not applied*** | 11,925 | 11,193 | 2,629 | 3,781 |
| Vitamin A - total (mcg) | ≥625 [900] | 416.6 | 694.4 | 625.0 | 625.0 |
| Thiamine (mg) | ≥1.0 [1.2] | 2.4 | 2.8 | 4.0 | 4.9 |
| Vitamin C (mg) | ≥30 [45] | 10.0 | 58.8 | 39.0 | 36.9 |
| Vitamin D (mcg) | No limit | 0.8 | 0.8 | 1.2 | 4.1 |
| Vitamin E (mg) | ≥10 (AI) | 8.9 | 19.5 | 11.0 | 14.6 |
| Zinc (mg) | ≥12 [14] | 33.0 | 23.6 | 14.0 | 16.8 |

**Notes:**

Bolded values in the table show levels below current EARs.

AI – Adequate intake as defined by the NHMRC.[15]

RDI – Recommended dietary intake.[15]

* Given the rigours of the military environment, we used the dietary energy provided in the military rations for the optimised diets (i.e., 18,212 kJ). For comparison, 11,450 kJ is the estimated energy requirement (EER),[15] averaged for four adult age-groups at the mid-range level of physical activity of 1.7 MJ/day. The latter relates to male weight sizes from 56.3 to 88.0 kg with a mid-range value of 71.3 kg. This compares to the mean enlistment weight of a New Zealand soldier of European ethnicity of 160 lbs or 72.6 kg.[19] Nevertheless, the 18,212 kJ in Scenario R-A is equivalent to 4,350 calories which is slightly more than estimates for frontline British and German troops in WW1 (at 4,193 and 4,038 respectively), but less than for US troops (at 4,714).[13]

** New Zealand Adult Nutrition Survey (NZANS).[16]

*** The recommended upper limit for sodium of 2300 mg[15] was not applied in our analyses as in the military situation, relatively higher sodium levels may have been more optimal for reducing food wastage from spoilage. Also losses of sodium via sweat during work in hot conditions might have increased sodium requirements – though probably still far below the estimated intake from the military rations as per Scenario R-A. Also at times of the year at Gallipoli it was also quite cold and so sodium losses via sweat would sometimes be fairly minimal.

**Table 4. Food sources of two key vitamins (A and C) in the actual official military rations (using two differing food composition databases, ordered by vitamin C levels)**

| Food items | Source of vitamin A (%) | | Source of vitamin C (%) | |
|---|---|---|---|---|
| | NZ Food composition data | USDA data | NZ Food composition data | USDA data |
| Corned beef (canned) | 23.3 | 0 | 45.2 | 0* |
| Jam | 0.1 | 0 | 29.6 | 86.1 |
| Bacon | 0 | 5.1 | 11.2 | 0** |
| Dried potatoes | 0.4 | 0.1 | 5.7 | 6.6*** |
| Biscuit | 0 | 1.2 | 4.5 | 3.5 |
| Dried peas | 1.1 | 0.5 | 3.8 | 3.9 |
| Cheese (cheddar) | 75.0 | 93.0 | 0 | 0 |
| Other# | 0 | 0 | 0 | 0 |
| **Total** | **100** | **100** | **100** | **100** |

**Notes:**

* The USDA database reports zero vitamin C for most beef products, though some vitamin C is reported in raw ox liver (at 1.3 mg / 100 g) which could potentially contribute if the canning process in 1915 included parts of this or other organ meats.

** The USDA does report vitamin C in fresh raw pork (0.7 mg / 100 g) but not in bacon.

*** Uses the vitamin C data for dried potato from the NZ food composition database (given the very high value from likely vitamin C fortification in the USDA database for dried potato). See the *Methods* section for further details.

# Includes: bread, flour, dried beans, salt, mustard, pepper and sugar.

**Table 5. Results with uncertainty intervals from 2000 iterations of the modelling around intakes of two key vitamins (A and C) in the official military rations in 1915 (Scenario R-A)***

| Statistics | NZ food composition data | | USDA food composition data | |
|---|---|---|---|---|
| | Vitamin A (mcg) | Vitamin C (mg) | Vitamin A (mcg) | Vitamin C (mg) |
| Mean | 312.4 | 7.2 | 181.6 | 6.1 |
| Median | 312.7 | 7.2 | 181.8 | 6.1 |
| 95% Uncertainty interval [UI]* | 291.4 to 332.4 | 6.5 to 7.8 | 169.4 to 193.3 | 5.5 to 6.7 |
| 99% UI* | 283.3 to 338.1 | 6.3 to 8.0 | 164.7 to 197.0 | 5.4 to 6.8 |

* When considering the factors of: food wastage and the variability of the likely variation in nutrient concentrations in foods (including vitamin C in dried potato). See *Methods* for further details.

## Discussion

**Main findings and interpretation—**The historical reports indicate the very limited variety of the military rations at Gallipoli and include additional factors that may have

impacted on food intake (e.g., supply to the front lines, harassment from flies, limited water supplies and low palatability of the food).

The nutritional analysis found that the military rations supplied at Gallipoli appeared to be deficient by modern nutritional standards (i.e., too low in: vitamins A, C, E, potassium, selenium and dietary fibre).

Furthermore, if the planners of military rations had made these rations somewhat more like the typical New Zealand diet in terms of modest amounts of canned vegetables and fruit (Scenario R-V), then this would probably have eliminated four of these deficits (i.e., including those for vitamins A and C). Other improvements would have been a reduction in the very high intakes of saturated fat and sodium. This higher variety diet (Scenario R-V) was estimated to only cost an estimated 40 cents per day more (albeit using modern pricing, i.e., $11.43 vs $11.03, Table 3).

The low vitamin C intake identified in this analysis (including in the uncertainty analysis) is entirely compatible with the medical reports of scurvy among the New Zealand soldiers at Gallipoli.[3] It also fits with other evidence from Gallipoli: "… scurvy broke out among the Indian troops at Gallipoli, and among the Turkish troops taken prisoners, there were many well-defined cases of scurvy, beriberi, and pellagra".[12] Our estimated 95%UIs of 6.5–7.8 and 5.5–6.7 mg/day for vitamin C in the rations (depending on nutrient data and wastage of food – Table 5), fit with the evidence for clinical signs of scurvy in adults occurring with intakes of 7–8 mg/day or less.[15]

But our estimates for vitamin C intake may still be overestimates since vitamin C content in foods would have been degraded by the drying and canning methods of the time, the long transport times of food to Gallipoli, and by cooking methods (e.g., prolonged heating and exposure to copper, iron or mildly alkaline conditions can destroy vitamin C; it can also be leached into water during cooking[15]).

Intake would have been impaired by reduced food intake from illness (widespread dysentery in these troops) and problems with food supply delivery to frontline troops (see above). Furthermore, tobacco was part of the rations supplied to the troops[3] and plasma vitamin C concentrations can be reduced by 40% in male smokers.[15] Finally, some individuals may have been particularly susceptible to scurvy as the more contemporary view is that it is a nutritional deficiency that is codetermined by genetic factors.[6]

Our analysis also showed deficient vitamin A intake but nearly all the uncertainty analysis results gave higher levels than for causing night blindness from vitamin A deficiency (i.e. below 165 mcg/day as reported in some studies,[20] though the lower bound of the 99%UI using USDA data was below this level). But our results are also possibly overestimates as the above reasons given for vitamin C intake around food supply and dysentery would also apply to lowering vitamin A intake and absorption.

So while we could find no medical reports of "night blindness" in these troops in the literature, it is plausible that some existed and was not reported (especially given past historical evidence for military populations with night blindness – see Introduction). Hence this deficiency could plausibly have increased injury risk if soldiers were more likely to be stumbling around at night (i.e., injury from enemy fire or falls).

Given the role of vitamin A in immune function and protecting against infectious disease mortality,[15] the low intake could well have contributed to the high mortality rate from dysentery in the Gallipoli campaign.

Other nutritional morbidity could have arisen from the high sodium in the military rations (Table 3). This would have exacerbated thirst that occurred when frontline troops were short of water which was a common situation at Gallipoli. The hardness of the biscuits was also considered a problem and was reportedly the main reason for visits to army dentists.[2]

Low dietary fibre in the military rations (especially when combined with water shortages), could have contributed to constipation and such related problems as haemorrhoids. But such problems would not be relevant at times when dysentery and typhoid were prevalent. Furthermore, the overall low variety and palatability of the food may have adversely impacted on military morale and mental health.

The comparison with "optimised" diets using foods available in 1915 is an artificial one as military planners in 1915 knew only about food costs and very little about nutrition. But this analysis does demonstrate the very large advances in modern knowledge combined with mathematical techniques and computerisation. That is only six foods (Scenario R-O) would be required to provide optimal nutrition and at under half the cost of the actual military ration in 1915. Even expanding the variety of foods beyond the military ration was cost saving when considering the purchase price (for 50 g+ items in Scenario R-OV).

**Study limitations—**As detailed above for vitamins A and C, our estimates of nutrient intake are probably overestimates for a range of reasons. But added to this is that the modern nutrient data of foods may not be fully comparable with the 1915 equivalents. For example, the modern food for which we used nutrient data for, may be more nutrient dense due to more efficient industrial scale harvesting and food processing. Modern canned food may have lower sodium levels and may reflect more modern preferences (e.g., with canned meat probably being less fatty).

Our estimates around the relative pricing of the different rations makes the crude assumption that *relative* prices between foods now are similar to those of 1915. Yet there have been many changes in agricultural and industrial techniques involved in food processing which may have influenced relative prices. We also do not consider how much a slightly heavier daily food ration in some scenarios might have impacted on transport costs by ship or from the beach depots at Gallipoli to the front lines.

The estimates used in the uncertainty analysis for food wastage (at 25%) are simplistic and could also be conservative. The uncertainty analysis also highlighted differences in the nutrient concentrations depending on the food composition database used (e.g., markedly so for vitamin C in canned corned beef). Given all these considerations, our nutritional analysis results should be considered as only "suggestive" and not definitive.

**The wider problem of poor planning—**The poor planning around low quality military food rations with lack of variety (no canned vegetables or fruit) and dominance of salty corned beef and limited water supplies could have been avoided if planners tried harder to better replicate the standard New Zealand diet at the time.

Furthermore, if military leaders and military medical personnel had appreciated the lessons from military history (e.g., the major problems of scurvy in the US Civil War[5]), then they may have ensured more fruit and vegetables were supplied to the troops.

It is possible that such risks were known by some, but that it was anticipated that the Gallipoli campaign would be short-lived and easily won. Certainly not one of the allied planners anticipated what followed. Instead of swift victory:

> There ensued stalemate and trench warfare perhaps even more ghastly than the Western Front, in which the stench of corpses rotting in the blazing sun of May, June and July blended in with the perfume of wild thyme, and the very narrowness of the front and rear areas added a dreadful claustrophobia.[21]

As the war progressed, there is considerable evidence on the Western Front that the New Zealand military tried to improve food quality (including provision of fresh vegetables).[11] Also New Zealand soldiers continually supplemented their diet by buying local produce particularly eggs and potatoes.

For the British Expeditionary Force as a whole, the quality and amount of food available improved considerably. Corned beef (bully beef), albeit varying in quality, was abundant. But as one soldier wrote to his parents: "We get plenty of tuck out here, bread, cheese and bacon and a butter issue twice a week and stew for dinner. It is a bit monotonous." [13 (p323)] Monotonous yes, but it would have been more nutritious than the Spartan nature of the Gallipoli rations. This diet was also supplemented by regular food parcels from home and by purchasing food from local people.

Food and water supplies were just one of a number of planning problems at Gallipoli. Other problems included inadequate clothing,[3] and lack of enough health services (including number of healthcare workers, medical supplies and hospital ships). Because of such problems during the Anzac landings and in the months that followed, "many did not get the surgery they needed".

As a New Zealand historian acknowledged: "If there was one thing that showed our unpreparedness for war on a large scale, it was the neglect to anticipate accommodation for wounded."[10 (p98)] Elliot also wrote in 1923 that "the high importance of hospital ships was not sufficiently recognised in the earlier stages of the Gallipoli campaign."[22]

Military planners were not anticipating such a prolonged and difficult campaign,[23] and all sides were surprised by the new scale and nature of industrialised warfare. But the major failure with Gallipoli may have been at the strategic level given the redundancy of the campaign when the outcome of WWI was always going to be determined on the Western Front.[23]

The nutritionally inadequate food rations for the New Zealand soldiers on Gallipoli was symptomatic of this poor planning, and was a feature that is likely to have contributed to cases of scurvy and other nutrition-related health problems.

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# Appendix 1

## Additional methods

**Approaches to uncertainty—**Uncertainty analysis was performed around the levels of vitamins A and C in the official 1915 military rations using the software "@Risk for Excel" (version 5.7 Palisade, Sydney). We ran 2000 iterations of the model and calculated 95% and 99% uncertainty intervals (UI). The analysis considered uncertainty arising from:

- The variation in levels of these vitamins in food (we assumed that the levels of vitamins A and C followed a normal distribution with a standard deviation equal to 5% of the mean value). In addition to the "New Zealand food composition database", we also considered the data in the US Department of Agriculture (USDA) database.[24]
- The exception to the above was that we excluded the USDA data for dried potato for vitamin C – as this was very high (at 81 mg/100 g and probably reflecting fortification of the product with vitamin C). Instead, for both the vitamin C estimates using NZ and USDA nutrient data, we applied loss estimates in the range of 82% to 96% (i.e., for the 95% uncertainty interval [UI], normally distributed). The former value represents an estimate for vitamin C loss from the drum-drying of potatoes (the same as the 82% loss for storage for 4.3 months at 25°C), and the latter value for the loss from preparation (i.e., reconstituting mashed potatoes and holding them 30 minutes on a steam table).[25] Other work for modern convective drying of potato also reports substantive vitamin C losses.[26]
- In the absence of good data on food wasted or lost in delivery to the battlefield, we just used the same point estimate (of 25%) for food waste from a modern UK study (Table 50 in the Report[27]). Then we assumed a normal distribution and used ±10% around the point estimate for the 95%UI.

**Nutrient analysis methods—**In Tables A1-A3 are details of the military rations in 1915 and our assumptions around modern equivalents and plausible additions.

## Table A1. Details of the daily 1915 military food rations and methods steps for further analysis

| Original specifications* | Equivalent used in our analysis (metric equivalents) | Comments |
|---|---|---|
| "1¼ lbs, Bread or 1 lb. Biscuit or 1 lb. Flour." | White bread (1.25 lb = 567 g) x 0.33<br>Biscuit (1 lb = 454 g) x 0.33<br>Flour (white) (1 lb = 454 g) x 0.33 | We assumed a third each of these three alternatives in the nutrient analysis. Of note was that in the early 1900s in NZ, white bread was preferred over brown (http://www.teara.govt.nz/en/food-and-beverage-manufacturing/6). |
| "3 ozs. Cheese." | Cheddar cheese (3 oz = 85 g) | We used cheddar cheese as this was the major form produced by NZ (http://www.teara.govt.nz/en/agricultural-processing-industries/2). |
| "¼ lb. Jam" | Jam (3 oz = 85 g) | We used a mix-fruit jam in our analysis. Plum and apple, and apricot were the most common jams used in the rations. |
| "1¼ lbs. Fresh Meat or 1 lb. (nominal) preserved meat." | Corned beef (1lb = 454 g) | We used corned beef (i.e., bully beef) as "fresh meat" was less commonly available in the military setting. |
| "4 ozs. Bacon." | Bacon (4 oz = 113 g) | We used fresh bacon as food composition data on former heavily salted forms was not available. The bacon in the rations was quite fatty and was nicknamed 'corporal' bacon – for the one or two strips of meat through it. |
| "2 ozs. Peas, Beans or dried Potatoes." | Dried peas (0.67 oz = 19 g)<br>Dried beans (0.67 oz = 19 g)<br>Dried potatoes (0.67 oz = 19 g) | We assumed a third of each of these 3 alternatives, but it is possible that in reality the cheapest item predominated: i.e., dried potatoes. |
| "½ oz. Salt" | Salt (0.5 oz = 14 g) | |
| "1/20 oz. Mustard." | Mustard (0.05 oz = 1.4 g) | |
| "1/36 oz. Pepper." | Pepper (0.028 oz = 0.8 g) | |
| "3 ozs. Sugar." | White sugar (3 oz = 85 g) | |

**Notes:**

* Included in the rations but which we excluded from our analysis were: "⅝ ozs. Tea." (since it provides no dietary energy) and the following since they were declared "discretionary": "1/10 gill Lime juice at discretion of G.O.C. on recommendation of S.M.O"; "½ gill Rum at discretion of G.O.C. on recommendation of S.M.O".

## Table A2. Further details on the foods used to replicate the military rations for 1915 (as per those listed in column two of Table A1)

| Food items | Specific modern product used in this analysis | Amount (g) / day | Price per 100 g (NZ$, 2011/12)* | Comments (see also Table A1) |
|---|---|---|---|---|
| Bread | White sliced loaf (cheapest brand) | 187 | 0.29 [FPI] | |
| Biscuit | Cabin bread used for the nearest equivalent | 150 | 1.00 | The type of hard biscuit used in 1915 has no precise modern equivalent but for the nutrient analysis we used cabin bread. |
| Flour | White (supermarket only) | 150 | 0.14 [FPI] | |
| Cheese | Mild cheddar (supermarket) | 85 | 1.02 [FPI] | |
| Jam | Supermarket brand (mixed fruit) | 85 | 0.45 | |
| Corned beef (canned) | Supermarket brand corned beef | 454 | 1.14 | |
| Bacon | Middle bacon product | 113 | 1.52 | |
| Dried peas | Split peas (green) | 19 | 0.34 | |
| Dried beans | Haricot beans | 19 | 0.55 | Price data obtained from another source: "Commonsense Organics online" |
| Dried potatoes | Instant potato (potato flakes) | 19 | 1.13 | |
| Salt | Table salt | 14 | 0.24 | |
| Mustard | Mild American style mustard | 1.4 | 1.66 | |
| Pepper | Supermarket brand pepper black ground | 0.8 | 2.98 | |
| Sugar | White | 85 | 0.20 [FPI] | |
| Total | | 1382.2 | | |

**Notes:**

FPI = Food price index (average monthly data for 2011).[17]

* Prices from the online store of a major supermarket chain "Countdown", unless otherwise indicated (March 2012). Lowest cost items were preferentially selected.

**Table A3. Additional types of dry or canned foods that could have been included in military rations for 1915 and which were included in our further nutritional modelling (along with those itemised in Table A1)***

| Food category / items | Specific modern product used in the analysis | Price per 100 g (NZ$, 2011/12)** | Comments (availability in NZ at the time of WWI) |
|---|---|---|---|
| **Cereals** | | | |
| Oats (rolled) | Branded "porridge rolled oats" | 0.41 | In NZ, "by 1890 porridge (cooked rolled oats), introduced by Scottish immigrants, was common" (http://www.teara.govt.nz/en/food-and-beverage-manufacturing/5). |
| **Fruit** | | | |
| Apricots (canned) | Supermarket brand apricot halves | 0.27 | Fruit canning was occurring in NZ in 1905 e.g., for apricots (http://www.teara.govt.nz/en/otago-region/6/5/2). Around 1910 a canning factory in Hawke's Bay made "various kinds of jam, canned peaches, pears, apricots, tomatoes, beans and peas, as well as pickles, spices, baking powder and lemon peel" (http://www.teara.govt.nz/en/food-and-beverage-manufacturing/4/1/1). |
| Peaches (canned) | Supermarket brand | 0.42 [FPI] | See above. |
| Pears (canned) | Branded pear halves in juice | 0.55 | See above. |
| **Vegetables*** ** | | | |
| Tomatoes (canned) | Supermarket brand tomatoes diced | 0.24 | See above. |
| Peas (canned) | Branded "peas garden minted" | 0.71 | See above. (Price also adjusted as the drained weight is used in the nutrient analysis). |
| Beans (canned) | Branded "four bean mix" | 0.83 | As above for peas. |
| **Meat, fish and dairy** | | | |
| Sheep meat (canned) | Branded "corned lamb" (lowest priced canned sheep meat) | 1.67 | NZ companies produced "canned fruit, jam, fish and meat from 1864" (http://www.teara.govt.nz/en/food-and-beverage-manufacturing/4). |
| Fish (canned) | Branded fish fillets smoked (NZ fish of unspecified species) | 2.00 | See above regarding canned fish. Price per 100 g has been adjusted to give the price for the drained weight (i.e., 200g /310 g). Nutrient analysis used canned tuna. |
| Milk powder (canned) | Supermarket brand skim milk powder | 1.00 | Canned milk powder was available e.g., Joseph Nathan and Company started making canned dried milk in 1904 at Bunnythorpe (http://www.teara.govt.nz/en/agricultural-processing-industries/2). |

**Notes:**

* Ignoring foods that could have potentially been purchased: (i) within the Mediterranean region e.g., from Greece: dried fruits, vegetables, olive oil; and (ii) on the international market e.g. canned sardines and canned salmon.

** Prices as per footnote for Table A1.

*** Canned baked beans and spaghetti in tomato sauce were not produced in NZ until the early 1930s.