The historical and projected prevalence of dysphagia in Aotearoa New Zealand

Philip Gunby, Josh McSkimming, Maggie-Lee Huckabee

ABSTRACT

AIM: To estimate the current prevalence of dysphagia in the Aotearoa New Zealand population and to project its prevalence to 2073.

METHODS: The current prevalence of dysphagia in Aotearoa New Zealand is computed from the prevalences of the aetiologies of dysphagia combined with the rates at which the aetiologies result in dysphagia. Projected dysphagia rates use autoregressive integrated moving average forecasting techniques combined with population projections from Statistics New Zealand and estimates of current and past prevalence rates of dysphagia.

RESULTS: The prevalence of dysphagia in Aotearoa New Zealand is estimated to have been approximately 1.78% in 2020, with the biggest aetiological contributors being stroke, Alzheimer's disease and other dementias, and gastroesophageal reflux disease. These three causes made up 81.5% of all estimated dysphagia cases in 2019. The prevalence rate of dysphagia in Aotearoa New Zealand is projected to rise to 2.54%, reflecting the ageing population.

CONCLUSION: An increased prevalence of dysphagia will result in an increased healthcare burden, both from resources spent on treating dysphagia and complications stemming from undiagnosed and thus untreated dysphagia. Estimating the full extent of this increased burden is hampered by the absence of systematic, extensive and reliable records available relating to cases of dysphagia in Aotearoa New Zealand.

Dysphagia is a potentially life-threatening condition that can have severe complications, such as aspiration pneumonia, malnutrition and dehydration. Many risk factors that cause dysphagia are associated with increasing age.[1] Since the median age of the Aotearoa New Zealand population is projected to increase from the current 37 years to 47 years by 2073, this will disproportionately increase conditions such as stroke and Parkinson's disease that can cause dysphagia.[2–4] While age-related health spending will increase significantly as the population ages, what is not clear is what will happen to the economic burden from specific conditions, such as dysphagia. Delineation of the economic implications of dysphagia will offer a valuable foundation on which to forecast service delivery costs and meet the health needs of patients with this condition.

Currently, the only estimates of the general prevalence rate for dysphagia are based on a few isolated sub-group studies. One study found that the risk of dysphagia among older people in the Aotearoa New Zealand district health board community was 3.5%, with the risk increasing to 32.1% for patients in aged residential care.[5] Another found a higher risk of dysphagia in a similar cohort of aged residential care patients in Aotearoa New Zealand, at 37.1%.[6] A further study concluded that the prevalence of dysphagia in older patients newly admitted to an Aotearoa New Zealand hospital was 29.5%.[7] An Australian and New Zealand Society for Geriatric Medicine study found a lower prevalence estimate of between 7% and 21% in the community.[8] While dysphagia commonly occurs from conditions associated with the elderly, it also results from traumatic brain injuries or congenital disorders, which occur in younger age groups. As much of the literature focusses on the elderly, these figures are therefore inadequate to estimate the prevalence of dysphagia in Aotearoa New Zealand's general population. Global studies are also of little generality to Aotearoa New Zealand as they tend to be from specific population sub-groups within specific conditions known to cause dysphagia.[9–11]

This paper estimates the historical prevalence of dysphagia in Aotearoa New Zealand's population and uses this to forecast this prevalence rate over a 50-year timespan. The result of this work is available to be used to calculate projections of future clinical resource needs to treat dysphagia and to calculate projections of the economic costs

of dysphagia in an ageing Aotearoa New Zealand population.

Method

Conventional methods estimate the prevalence of a medical condition using recorded cases or estimate the number of cases and therefore the prevalence rate from representative population samples.[12–14] These are not applicable to Aotearoa New Zealand as there exists no detailed public information on the number of dysphagia cases or age-specific incidence rates of dysphagia. Similarly, little information exists about the prevalence of dysphagia in Aotearoa New Zealand representative groups. In response, the prevalence rate is estimated using the prevalences of the underlying conditions that cause dysphagia. These are then used to indirectly compute the number of historical dysphagia cases in a method similar to Brookmeyer and Gray.[12]

Method for estimating the historical prevalence rate of dysphagia

Historical case numbers of dysphagia are estimated using a flow-based model. Each year, individuals can potentially develop a condition that could cause dysphagia at a time-varying prevalence rate, with an associated time invariant probability of then developing dysphagia from that condition. The resulting numbers of dysphagia cases across all conditions are then aggregated to get a total figure. This is combined with historical population figures to calculate the annual prevalence rate of dysphagia.

This approach allows for changing demographics to affect the underlying conditions that cause dysphagia. This is because the impacts of demographic movements are reflected in the prevalence rates and case numbers of the underlying conditions that cause dysphagia, which are allowed to vary over time as demographics change. The constant condition-specific prevalence rates of dysphagia effectively imply that dysphagia developed as a secondary result of a condition is independent of demographic population changes.

Data for the prevalence of causes

Data concerning the prevalence and case numbers of conditions that cause dysphagia in Aotearoa New Zealand, except for traumatic brain injuries, are obtained from the 2019 Global Burden of Disease (GBD) Study.[15] GBD data can also be used to calculate 95% upper and lower bound estimates for each condition prevalence around their midpoint estimate, which are then used to perform a sensitivity analysis of the dysphagia prevalence estimates.[16] Another study is used to determine the number of traumatic brain injury cases in Aotearoa New Zealand each year.[17–18] This study finds that the Aotearoa New Zealand–specific age-standardised rate of existing traumatic brain injuries is 534 per 100,000, with 95% upper and lower bound estimates of 561 per 100,000 and 508 per 100,000. This rate is applied to the population each year to compute the number of traumatic brain injury cases, assuming a constant population age-standardised prevalence rate for traumatic brain injury between 1990 and 2019.

Cause-specific dysphagia prevalence data

Most of the condition-specific prevalence rates of dysphagia are obtained from a 2018 literature review on causes of dysphagia among different age groups.[19] Simple averages of the upper and lower bounds from the study are used to form the midpoint prevalence rates for each condition. These are used to form the central estimates from the method and models. Another study is used in the same way for the traumatic brain injury–specific prevalence rate of dysphagia.[10] Table 1 includes the cause of dysphagia, the GBD condition that cause is related to and the upper, lower and midpoint estimates of the condition-specific rate of dysphagia prevalence. In situations where conditions that cause dysphagia are a subcategory of a larger condition in the GBD study, a simple average prevalence rate of the subcondition rates is used to form an overall prevalence rate for that condition. For example, in the 2019 GBD Study, head and neck cancer (HNC) has one prevalence measure even though multiple forms of HNC occur and each have their own dysphagia prevalence rate.

Another important condition that causes dysphagia is gastroesophageal reflux disease (GRD).[20] This condition can cause swallowing difficulties and result in dysphagia in severe or long-term cases of GRD.[21] The 2019 GBD Study shows that GRD is relatively common in Aotearoa New Zealand, with an estimated 534,050 cases or 10.5% of the 2019 population. The GBD study unfortunately uses a broad definition of GRD and includes many mild cases that have a low risk of causing dysphagia.[22] Therefore, the GRD-specific rate of dysphagia is assumed to be represented

Table 1: Midpoint estimate of the prevalence of dysphagia among different causes with upper and lower bounds.

Cause	Associated Global Burden of Disease condition	Lower prevalence rate (%)	Upper prevalence rate (%)	Midpoint prevalence rate (%)
Stroke[19]	Stroke	25	81	53
Alzheimer 's disease[19]	Alzheimer's disease and other dementias	7	29	18
Frontotemporal dementia[19]	Alzheimer's disease and other dementias	19	57	38
Parkinson's disease[19]	Parkinson's disease	15	87	51
Multiple sclerosis[19]	Multiple sclerosis	24	34	29
Amyotrophic lateral sclerosis[19]	Motor neurone disease	86	86	86
Reflux disease[19]	Gastroesophageal reflux disease	6	50	28
Head and neck cancer (pre-treatment)[19]	Head and neck cancer	9.2	67	38.1
Head and neck cancer (post-treatment)[19]	Head and neck cancer	23	100	61.5
Oesophageal squamous cell carcinoma[19]	Oesophageal cancer	62	93	77.5
Oesophageal adenocarcinoma[19]	Oesophageal cancer	53	79	66
Anaplastic thyroid cancer[19]	Thyroid cancer	40	40	40
Traumatic brain injury[10]	Traumatic brain injury	27	30	28.5

by the reported lower estimate of 6% to avoid over-estimating the number of dysphagia cases from this condition.

Population data

Estimates of Aotearoa New Zealand's historical population are available using Statistics New Zealand's (Stats NZ) Infoshare tool[23] in each discrete year for the period from 1990 until 2019.

Method for projecting the prevalence of dysphagia

Once the historical case numbers and the prevalence rates of dysphagia have been estimated, we use an autoregressive integrated moving average (ARIMA) model to project dysphagia cases into the future.[24–26] A constant growth rate model, a linear model and a quadratic model are estimated as robustness checks.

Each model is fitted to historical data, with the number of dysphagia cases in each year as

the dependent variable and discrete time as the independent variable. This captures any impacts of changing demographics within the trend of each model through the historical case numbers and prevalence of the underlying conditions that cause dysphagia, and the rate at which individuals contract these conditions. As demographic changes are reflected in these variables, the past behaviour of the dysphagia case numbers also includes these changes. The results for each model contain the forecast of dysphagia case numbers for a particular year.

The ARIMA framework allows many attributes of a time series to be represented in a single model. The autoregressive term determines the number of lagged values of the dependent variable to include and captures how much the current value depends on what has happened in the past. The order of integration specifies the number of times the series is differenced to achieve stationarity to ensure validity of the statistical methods used to forecast the variable. The Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test is used to check for the presence of a unit root.[27] This is complemented with a visual analysis of the autocorrelation function to determine the degree of stationarity. The minimum Akaike information criterion (AIC) determines the level of differencing required to achieve stationarity. When forecasting the number of dysphagia cases, any future error terms are replaced with zero and the previous steps are used to determine the number of lagged values of the dependent variable and the error term, which are used with the computed regression coefficients to provide a forecasted value at each step.

The first comparison model uses the historical growth rate of dysphagia case numbers to compute the geometric average growth rate in the dysphagia case numbers that have occurred historically. The second uses historical dysphagia cases as a dependent variable with discrete time as the independent variable. Estimates from this linear model are then used to forecast the prevalence rate of dysphagia by extrapolation of the linear trend into the future for which population projections exist. The quadratic regression comparison model uses ordinary least squares (OLS) fitted to historical dysphagia cases with linear and quadratic time independent variables. This incorporates any potential quadratic trend resulting from the growth in the number of dysphagia cases. Extrapolation uses estimates of the coefficients from the quadratic model as well as the future time period parameters for forecasting.

Finally, the model results are combined with population projections from Stats NZ to estimate the future prevalence rates of dysphagia. Aotearoa New Zealand population projections are available for 2020, 2023 and every 5 years following 2023 until 2073 using Stats NZ's NZ.Stat tool.[2]

Results

The results are expressed as estimates of the number of dysphagia cases and of the prevalence rate of dysphagia. While these are linked, the rate of prevalence for dysphagia is based on forecasts of the underlying case numbers in order to capture demographic changes rather than the rate of prevalence itself. Thus, output and regression coefficients for each model correspond to changes in the number of dysphagia cases over time.

Historical results

The estimated historical Aotearoa New Zealand dysphagia prevalence rate shows a steady increase over time, as shown in Figure 1. Dysphagia is estimated to have affected 55,162 individuals in 1990 (a prevalence rate of 1.58%) increasing to 89,253 individuals by 2019 (a prevalence rate of 1.76%). The estimated number of cases has risen by 61.8% and the prevalence rate increased by 0.18 percentage points. Yearly growth in the number of cases varies between 0.93% and 2.07%.

A 5-year breakdown of the estimated number of dysphagia cases and the prevalence rate is

Table 2: Five-year breakdown of historical dysphagia cases and prevalence.

Year	1990	1995	2000	2005	2010	2015	2019
Number of dysphagia cases	55,162	58,676	63,656	69,253	75,952	82,700	89,253
Dysphagia prevalence rate (%)	1.58	1.58	1.64	1.66	1.73	1.77	1.76

Figure 1: Estimated historical dysphagia prevalence rate and case numbers in Aotearoa New Zealand.

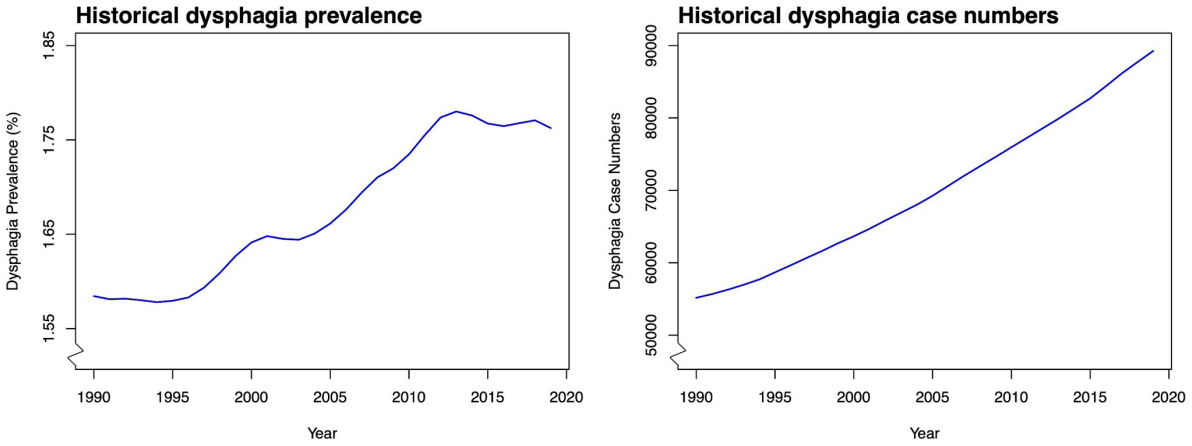


Figure 2: Forecasts of dysphagia prevalence rate and case numbers in Aotearoa New Zealand.

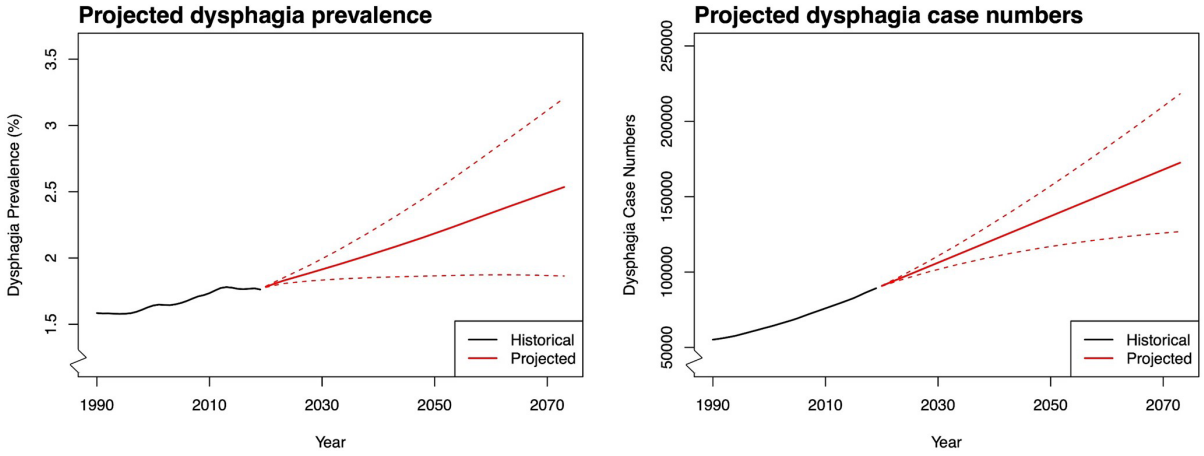


Figure 3: Forecasts of dysphagia prevalence rates and case numbers by model.

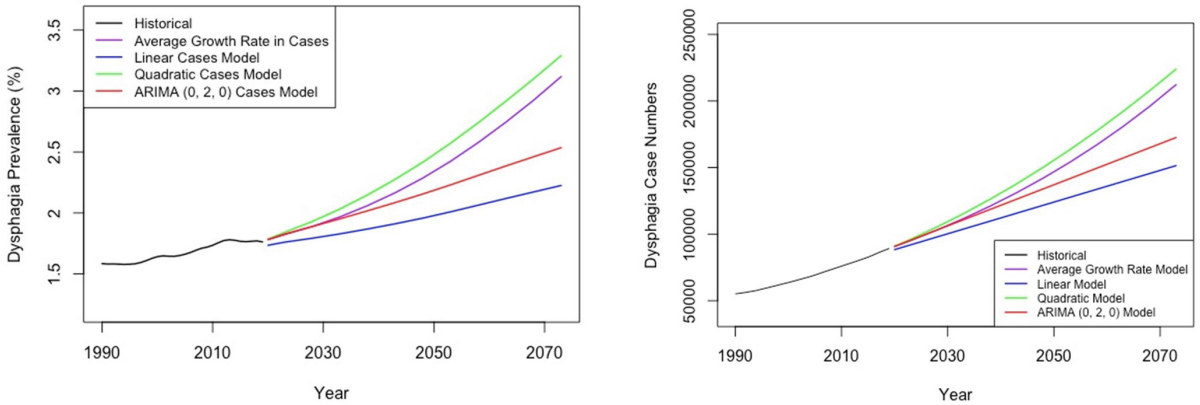
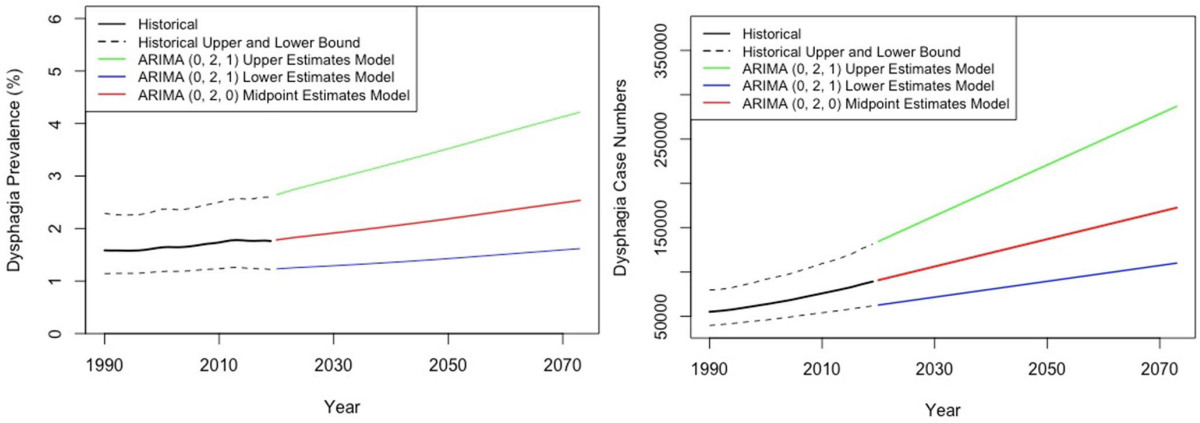


Figure 4: Forecasts of dysphagia prevalence rates and case numbers using ARIMA models on lower, midpoint and upper values of independent variables.



shown in Table 2. While the estimated number of past dysphagia cases shows an exponential trend, the historical population growth rate in Aotearoa New Zealand varies over time. This results in the rate of dysphagia prevalence rising over certain periods and remaining relatively stable during others.

Forecasted results

The ARIMA model is the main model used for forecasting the number of dysphagia cases. In testing the historical case numbers for stationarity, the KPSS test is only accepted (p-value >0.1) at the second difference, which is confirmed by analysis of the autocorrelation function. Therefore, a second difference (order 2) ARIMA model is used for forecasting. Furthermore, the AIC is lowest (AIC=339.56) with no moving average or autoregressive terms.

Figure 2 displays the forecasted prevalence rate and case numbers of dysphagia, plus 95% uncertainty intervals (dashed lines), from the fitted ARIMA (0, 2, 0) model. Forecasted case numbers and prevalence rate values are in Table 3. The prevalence rate is forecast to rise to approximately 2.2% by 2050, with over 130,000 individuals affected by dysphagia. This rises to an estimated 172,529 individuals by 2073, or just over 2.5% of the general Aotearoa New Zealand population. This represents an increase of 93.3% over the current number and a 0.78 percentage point increase in the prevalence rate. The case numbers display exponential growth, similar to what is seen historically. The uncertainty intervals become wider as time progresses, owing to the longer time horizon over which forecasting takes place.

The forecasts from the other three models show a similar pattern for both the forecast numbers and prevalence rates of dysphagia. Figure 3 shows a comparison of the projected prevalence rate and case numbers of the main ARIMA model with the alternative models (Appendix Table 1 and 2 contain side-by-side comparisons of the numbers of cases and prevalence rates).

There is little difference in projected prevalence rates between each model for the first 5–10 years. However, the difference between the forecasted prevalence rates widens as the forecast horizon lengthens. The quadratic model produces the highest forecast estimates and is distinctly non-linear in nature. The average growth rate model shows similar characteristics. Both models produce a forecast of the prevalence rate above the ARIMA model, especially later in the time horizon. In contrast, the linear model produces lower predictions for the future prevalence rate of dysphagia in Aotearoa New Zealand than the ARIMA model.

Sensitivity analysis of the ARIMA forecasts of the prevalence rate of dysphagia

Sensitivity analysis is used to assess the robustness of the forecasts of dysphagia obtained from the main ARIMA model. This involves recalculating historical dysphagia case numbers, fitting new ARIMA models and then making new forecasts based on them. This uses the 95% confidence lower and upper bounds for the historical case numbers for each condition causing dysphagia provided in the 2019 GBD data. The most efficient model for all scenarios based on the AIC involves two orders of differencing. However, each now includes one lagged error term. Forecasts of the number of dysphagia cases and prevalence rates with their upper and lower bounds are calculated

Table 3: ARIMA (0, 2, 0) forecast of dysphagia case numbers and prevalence rate (95% lower and upper bounds in brackets).

Year	2020	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073
Forecasted number of dysphagia cases	90,795 (90,598–90,992)	95,421 (94,344–96,499)	103,132 (99,811–106,453)	110,843 (104,576–117,110)	118,554 (108,777–128,330)	126,264 (112,494–140,035)	133,975 (115,780–152,170)	141,686 (118,673–164,699)	149,397 (121,203–177,590)	157,108 (123,394–190,821)	164,818 (125,266–204,371)	172,529 (126,835–218,224)
Forecasted dysphagia prevalence rate (%)	1.78 (1.78–1.79)	1.83 (1.81–1.85)	1.89 (1.83–1.95)	1.95 (1.84–2.06)	2.02 (1.85–2.18)	2.09 (1.86–2.31)	2.16 (1.86–2.45)	2.23 (1.87–2.60)	2.31 (1.87–2.74)	2.39 (1.87–2.90)	2.46 (1.87–3.05)	2.54 (1.86–3.21)

for each estimated model, shown in Figure 4. Appendix Table 3 contains the numbers of cases and prevalence rates.

Each scenario predicts that the prevalence of dysphagia in Aotearoa New Zealand will steadily increase. Additionally, the sensitivity analysis shows that the results corresponding to the lower bounds of the explanatory variables are closer to the midpoint outcomes than the results corresponding to the upper bounds. This is a result of the non-symmetrical 95% confidence intervals reported in the GBD study.

Discussion

This study has addressed a major shortcoming about dysphagia in Aotearoa New Zealand—a lack of information about its general prevalence, and about its historical and likely future trends. We estimate the prevalence of dysphagia in Aotearoa New Zealand to be approximately 1.78% in 2020. Over 81.5% of the total number of estimated dysphagia cases are due to Alzheimer's disease and other dementias, and GRD. The analysis shows that the historical prevalence rate has been increasing and is likely to increase significantly over the next 50 years. This trajectory reflects an ageing Aotearoa New Zealand population, leading to the fastest growing causes of dysphagia being thyroid cancer, oesophageal cancer and Alzheimer's disease and other dementias.

In terms of related literature, a recently published related study found similar forecast outcomes, although it used a different approach.[28] One point of difference is that our approach allows for estimates of historical case numbers and prevalence rates of dysphagia. Another key difference is that our method results in higher forecasted New Zealand dysphagia case numbers and prevalence rates out to the mid-2040s. This is because our approach covers more conditions that cause dysphagia, and thus incorporates more complete effects of population demographic changes. After this period, the impact of an ageing population dominates other factors and our forecasts are similar.

While our study is an important first step, its limitation is that it estimates the dysphagia prevalence indirectly. We used an indirect method to estimate the prevalence of dysphagia because there exist no systematic, extensive and reliable records about dysphagia in Aotearoa New Zealand. This suggests a need for a common national data framework for defining relevant medical conditions and practices, for collecting and storing data of all medical conditions and practices and for making data available to researchers to analyse trends and needs within the Aotearoa New Zealand health system.

Regardless of whether the actual rate is a bit above or below our estimate, the overall magnitude and trend of the prevalence rate are still valid. The finding that the prevalence rate of dysphagia in Aotearoa New Zealand is likely to increase significantly highlights that the associated healthcare burden will likely increase substantially. Some of this will be in terms of resources required for the treatment of dysphagia, in which case advancing treatment technologies and methods now could avoid significant treatment costs in the future. Some of the burden will be from treating complications in patients from conditions resulting from undiagnosed dysphagia, such as aspiration pneumonia. A 2018 meta-analysis by Attrill et al. documented that a dysphagia case created a further burden on healthcare costs of 40.36%.[29] Undiagnosed dysphagia creates an even higher eventual burden per case. Investing resources to better recognise and diagnose dysphagia would allow for saving resources from avoidance of complications caused from undiagnosed dysphagia. Wilson and Howe investigated cost-effectiveness of the videofluoroscopic swallowing study compared to clinical methods for evaluation of swallowing related to stroke. Incorporation of an early radiographic exam for dysphagia was more effective and less costly than clinical swallowing evaluation alone.[30] Finally, some of this burden will be borne through a lower quality of life and premature death if dysphagia is undiagnosed or treatment is delayed. Developing better ways to recognise and diagnose dysphagia and advancing treatment technologies and methods would mean those affected have a higher quality of life and longer lifespan.

COMPETING INTERESTS
MLH is a founding Board Member of SwalTech Ltd and a Board Member of Capistrano Charitable Trust.

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Appendix

Appendix Table 1: Forecasted dysphagia case numbers for ARIMA, linear, quadratic and historical growth models.

Year	2020	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073
ARIMA	90,954	96,126	105,373	115,406	126,223	137,824	150,211	163,382	177,338	192,079	207,605	223,915
Linear	88,359	91,930	97,881	103,833	109,785	115,736	121,688	127,639	133,591	139,542	145,494	151,445
Quadratic	90,954	96,126	105,373	115,406	126,223	137,824	150,211	163,382	177,338	192,079	207,605	223,915
Historical growth	90,696	95,167	103,114	111,724	121,054	131,162	142,115	153,982	166,840	180,772	195,867	212,223

Appendix Table 2: Forecasted dysphagia prevalence rates for ARIMA, linear, quadratic and historical growth models.

Year	2020	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073
ARIMA	1.78	1.82	1.89	1.97	2.06	2.17	2.29	2.42	2.58	2.74	2.92	3.12
Linear	1.73	1.76	1.79	1.83	1.87	1.91	1.96	2.01	2.06	2.12	2.17	2.23
Quadratic	1.79	1.84	1.93	2.03	2.15	2.28	2.42	2.57	2.74	2.92	3.1	3.29
Historical growth	1.78	1.82	1.89	1.97	2.06	2.17	2.29	2.42	2.58	2.74	2.92	3.12

Appendix Table 3: Forecasts of dysphagia case numbers and prevalence rates using ARIMA models on midpoint, lower and upper values of independent variables.

Year	2020	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073
Midpoint case numbers forecast (prevalence)	90,795 (1.78%)	95,421 (1.83%)	103,132 (1.89%)	110,843 (1.95%)	118,554 (2.02%)	126,264 (2.09%)	133,975 (2.16%)	141,686 (2.23%)	149,397 (2.31%)	157,108 (2.39%)	164,818 (2.46%)	172,529 (2.54%)
Lower case numbers forecast (prevalence)	55,759 (1.09%)	58,149 (1.11%)	62,134 (1.14%)	66,118 (1.16%)	70,103 (1.19%)	74,087 (1.22%)	78,071 (1.26%)	82,056 (1.29%)	86,040 (1.33%)	90,024 (1.37%)	94,009 (1.40%)	97,993 (1.44%)
Upper case numbers forecast (prevalence)	135,306 (2.66%)	143,907 (2.76%)	158,242 (2.90%)	172,576 (3.04%)	186,911 (3.18%)	201,245 (3.32%)	215,580 (3.47%)	229,914 (3.62%)	244,249 (3.77%)	258,583 (3.93%)	272,918 (4.07%)	287,252 (4.22%)