Metabolic risk factors and long COVID: a cross-sectional study in Aotearoa New Zealand

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ABSTRACT

AIM: To describe the association between metabolic risk factors and the risk of developing long COVID in Aotearoa New Zealand.

METHODS: Individuals aged 16 years and above who had confirmed or probable COVID-19 before December 2021 were eligible for inclusion. Metabolic risk factors were high body mass index (BMI, ≥25kg/m^2), high blood pressure, diabetes, heart disease and stroke. Logistic regression was used to estimate the association between metabolic risk factors and long COVID.

RESULTS: Of the 990 survey respondents, 21.9% met the definition of long COVID. After adjusting for socio-demographic factors, COVID-19 vaccination and hospitalisation, high BMI was strongly associated with long COVID (adjusted odds ratio [aOR] 2.35; 95% confidence interval [CI] 1.33–4.17, p=0.003). There was a suggestion of an association between heart disease and long COVID (aOR 4.31; 95% CI 0.80–23.3, p=0.090). No other metabolic factors were associated with long COVID. Among Māori, no associations were found between high BMI and long COVID compared with underweight/normal BMI.

CONCLUSION: High BMI as a risk factor adds to accumulating evidence on the aetiology of long COVID.

Many studies have reported participants experiencing prolonged, relapsing or exacerbated COVID-19 symptoms.[1] "Long COVID" is a term used to refer to ongoing or new symptoms 3 months after the initial onset of COVID-19, with symptoms that last for at least 2 months and cannot be explained by an alternative diagnosis.[2] Other labels that refer to long COVID have been used interchangeably, such as "post-COVID syndrome", "persistent COVID", "chronic COVID" and "long haul COVID".[3] The international incidence of long COVID has been estimated to be between 4 and 14% per infection,[4,5] with similar results demonstrated in Aotearoa New Zealand.[6] Long COVID can affect various organ systems, with manifestations involving the lungs, brain and cardiovascular systems.[3] Even those with mild presentations of COVID-19 can experience medium- to long-term impacts.[3]

Metabolic syndrome includes interrelated cardiometabolic abnormalities such as insulin resistance, abdominal obesity, elevated blood pressure, atherogenic dyslipidaemia (hypertriglyceridemia and/or low high-density lipoprotein cholesterol) and is a significant determinant of the global burden of cardiovascular disease.[7] These abnormalities can affect an individual's immune response,[8] and illnesses, including high blood pressure, diabetes, heart disease and obesity, have been reported to be associated with COVID-related hospitalisations and mortality.[9,10] These same illnesses have also been reported as determinants of long-term morbidity in other infectious diseases, suggesting a possible role as risk factors in long COVID.[8,11]

Previous international literature has reported a higher risk of long COVID in those with a high body mass index (BMI).[11–13] A systematic review and meta-analysis found that a BMI of ≥30kg/m^2 was associated with long COVID (odds ratio [OR] 1.15; 95% confidence interval [CI] 1.08–1.23) compared with a BMI of <30kg/m^2, with the associations present in both those hospitalised with COVID-19 and those not.[14] Similarly, a second meta-analysis identified obesity and diabetes as potential risk factors for long COVID.[15] Obesity, in particular, was associated with poorer health than that of non-obese participants due to a higher number of long COVID symptoms, longer symptom persistence and a higher prevalence of pathological pulmonary limitations and metabolic abnormalities.[15]

Despite these findings, our understanding of the pathogenesis of long COVID remains limited. The pattern of COVID-19 illness in Aotearoa New Zealand was different to overseas experiences, particularly the high rates of COVID-19 vaccination before infection. To date, no studies have examined metabolic risk factors associated

with long COVID in Aotearoa New Zealand. This presents an opportunity to gather national evidence specific to the population, including evidence specific to Māori.

Methods

The analysis used data from the nationwide *Ngā Kawekawe o Mate Korona | Impacts of COVID-19 in Aotearoa* study. Full details have been previously reported.[16] Briefly, those over the age of 16 years who had confirmed or suspected COVID-19 before December 2021 and were not living in a dementia unit were eligible for inclusion.[16] The Ministry of Health (MOH) sent letters of invitation to participate in the study, followed by two reminder SMS (text messages). A Tiriti o [Treaty of] Waitangi Relationship Framework underpinned the research, based on the assertion that co-governance between Māori and non-Māori is fundamental to achieving positive research outcomes.[16] Quantitative data were collected via four online survey modules between February and June 2022 through the study's website (www.covidaotearoa.com). The survey topics comprised: a) support and wellbeing, b) health and health services, c) cost of COVID-19, and d) long COVID (on which this analysis is based). All survey modules were available to complete concurrently, and participants were not required to complete every survey module. If participants preferred, surveys could be completed over the phone with a research team member.

Outcome and exploratory variables

The presence of metabolic risk factors was self-reported. Participants were asked if they had a pre-existing diagnosis of high blood pressure, heart disease, diabetes or stroke. A participant's BMI was calculated from self-reported height and weight and was categorised as "high" (≥25kg/m^2) or "underweight/normal" (<25kg/m^2). The primary outcome was the presence of COVID-19 and/or long COVID symptoms that persisted for 3 or more months from the time of acute illness ("long COVID"), as identified from a predefined list.[17,18]

We assessed the role of the following sociodemographic factors as possible confounders in multivariate regression models: age group, prioritised ethnicity (Māori, Pacific, Asian and Other),[19] gender, education and pre-existing disability before contracting COVID-19 ("pre-COVID disability").[20] Income struggle, defined as a self-reported struggle within the household to pay for essential living costs such as food, bills or accommodation in the first month of having COVID-19,[21] and household crowding, defined as more than two people per bedroom,[22] were used as markers of socioeconomic position. We also considered the potential confounding effect of having had at least one dose of the COVID-19 vaccine and hospital admission for COVID-19.

Missing data manipulation

For binary variables such as household crowding, pre-COVID disability, high blood pressure, diabetes, heart disease and stroke, any missing data were analysed with the unexposed group. For categorical variables, missing information was recoded into the largest existing group. As few participants did not specify their gender or identified as "Other gender" (<1%), these people were analysed with the "female" group. However, as nearly a third of participants (n=126/405, 31.1%) did not answer the question concerning income struggle, missing data for this variable were treated as a separate category.

A third of participants (n=137/405, 33.8%) did not report their height and/or weight for BMI calculations; we used three approaches to deal with missing data. In our *a priori* main analysis, those with missing height and/or weight were treated as a distinct category. Then, a sensitivity analysis was undertaken to account for possible misclassification in the reporting of BMI. In one scenario, all participants with missing data were analysed with the underweight/normal BMI group; in a second scenario, those with missing data were analysed with the high BMI group.

Statistical analyses

Percentages of each category of all variables were tabulated separately for people with and without long COVID. Logistic regression was used to estimate crude ORs and 95% CIs of the association between possible risk factors and long COVID. This was followed by a multivariable model adjusting for all potential confounders, for which we have the data simultaneously. Analyses were conducted using Stata (Version 16). Conventional levels of statistical significance were defined as P<0.05; however, due to the small numbers of people in some categories, focus was placed on the magnitude of effect sizes.

Ethics

Ethical approval was given by the Health and Disability Ethics Committee on 15 January 2022 (ref: 2021, EXP 11900). An amendment was

approved on 26 April 2022 (ref: 2022 AM 11900).

Results

Letters of invitation were estimated to have been delivered to 8,012 of the 8,735 participants whose positive COVID-19 test had been reported to the MOH before December 2021. Fourteen percent (n=1,227) of those who received an invitation began the survey, and 990 participants answered at least one of the four available survey modules, equating to a response rate of 12.4%.

Accounting for all people identified by the MOH who had a positive COVID-19 test before December 2021, 2.5% (n=217/8,737) reported long COVID. Of those who answered at least one survey, 21.9% (n=217/990) reported long COVID. This analysis is based on those participants who answered the long COVID survey module (n=405/990, 40.9%), of whom 53.6% (n=217/405) reported long COVID. A flow diagram of the study recruitment process is presented in Figure 1.

Characteristics of the participant cohort on which this analysis is based are shown in Table 1. Most participants with long COVID identified as female (71.9) and were mostly between 25 and 44 years (41.5%). Nearly half with long COVID (46.9%) were classified as having a BMI of ≥25kg/m^2. The risk of long COVID in Pacific peoples was lower than in the "Other" ethnic group, which primarily consisted of NZ Europeans. There was an apparent protective effect of having at least one COVID-19 vaccination and the risk of developing long COVID compared with those not vaccinated.

Associations between metabolic risk factors and long COVID are shown in Table 2.

Figure 1: Flow diagram of study participant recruitment process.

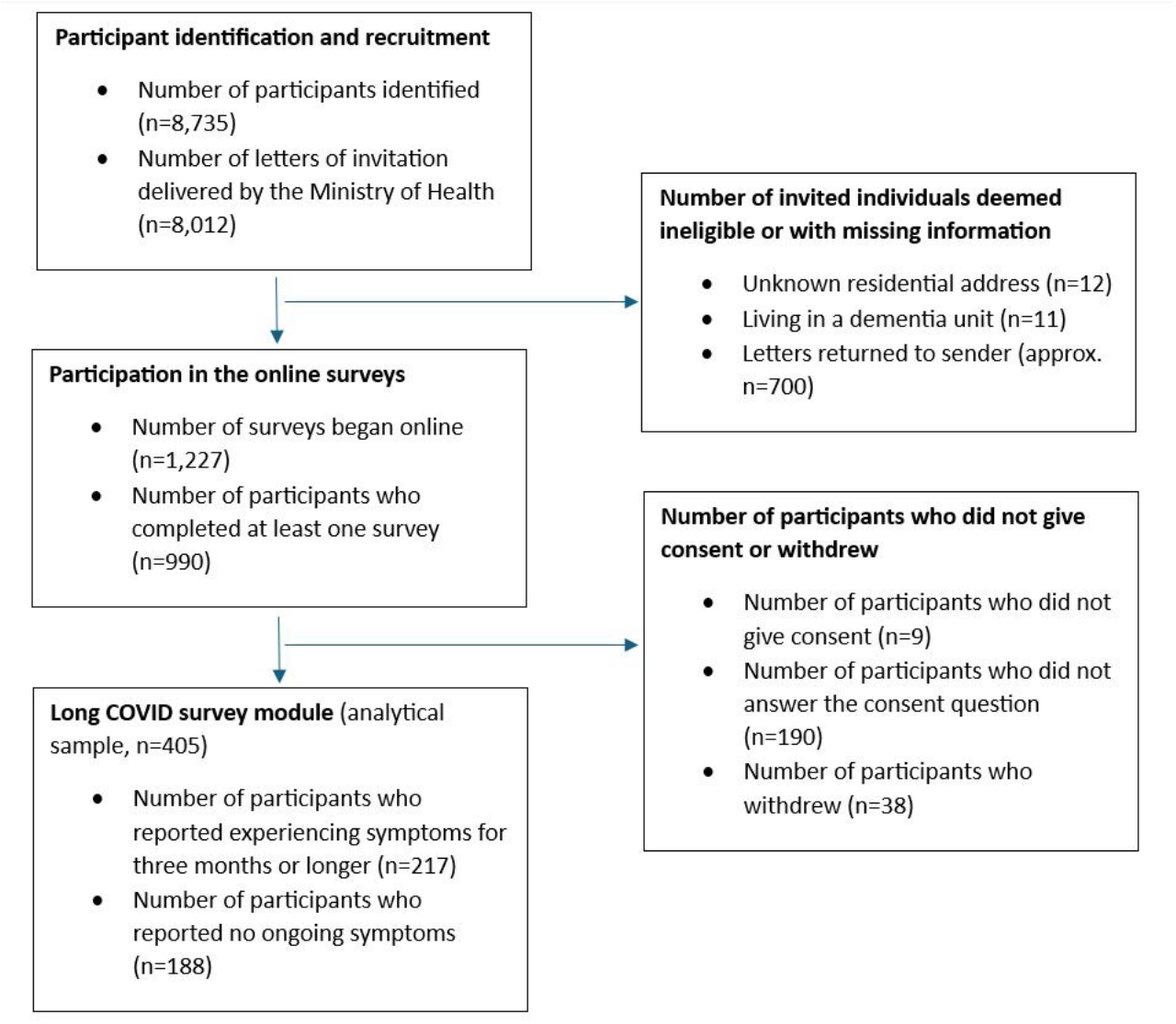

Table 1: Participant characteristics and the association between exposure variables and long COVID among 405 people in Aotearoa New Zealand.

Variable	Category	LC (%) n=217	No LC (%) n=188	OR (95% CI)	p-value
Age	15–24	21 (9.7)	21 (11.2)	0.89 (0.45–1.75)	0.73
	25–44	90 (41.5)	80 (42.6)	Reference	
	45–64	86 (39.6)	67 (35.6)	1.14 (0.74–1.77)	0.56
	65+	20 (9.2)	20 (10.6)	0.89 (0.45–1.77)	0.74
Gender	Male	61 (28.1)	60 (31.9)	Reference	
	Female	156 (71.9)	128 (68.1)	1.20 (0.78–1.84)	0.40
Ethnicity	Māori	33 (15.2)	28 (14.9)	0.90 (0.52–1.57)	0.72
	Pacific peoples	3 (1.4)	15 (8.0)	0.15 (0.04–0.54)	0.004
	Asian	9 (4.2)	13 (6.9)	0.53 (0.22–1.28)	0.16
	Other	172 (79.3)	132 (70.2)	Reference	
Education	School	46 (21.2)	38 (20.2)	1.02 (0.62–1.68)	0.94
	Post-school	44 (20.3)	43 (22.9)	0.86 (0.53–1.41)	0.56
	University	127 (58.5)	107 (56.9)	Reference	
Income struggle	Strongly agree/ agree	29 (13.4)	24 (12.8)	1.19 (0.65–2.21)	0.57
	Neither agree nor disagree	25 (11.5)	22 (11.7)	1.12 (0.59–2.14)	0.72
	Disagree/ strongly disagree	90 (41.5)	89 (47.3)	Reference	
	Missing	73 (33.6)	53 (28.2)	1.36 (0.86–2.16)	0.19
Household crowding	Overcrowding	10 (4.6)	12 (6.4)	0.71 (0.30–1.68)	0.43
	None	207 (95.4)	176 (93.6)	Reference	
Pre-COVID disability	Pre-COVID disabled	23 (10.6)	13 (6.9)	1.60 (0.78–3.25)	0.20
	Non-disabled[i]	194 (89.4)	175 (93.1)	Reference	
COVID Vaccination	Vaccinated	126 (58.1)	123 (65.4)	0.73 (0.49–1.10)	0.13
	Unvaccinated	91 (41.9)	65 (34.6)	Reference	
Hospitalisation with COVID	Hospitalised	23 (10.6)	19 (10.1)	1.05 (0.56–2.00)	0.87
	Not hospitalised	194 (89.4)	169 (89.9)	Reference	

LC = long COVID; OR = odds ratio; 95% CI = 95% confidence interval.
[i]Non-disabled cohort also includes participants who identified as having a disability that began after COVID-19 infection (n=30).

Table 2: Crude association between metabolic risk factors and long COVID among 405 people in Aotearoa New Zealand.

Variable	Category	LC (%) n=217	No LC (%) n=188	OR (95% CI)	p-value
BMI	High (≥25kg/m^2)	104 (47.9)	86 (45.7)	2.16 (1.25–3.72)	0.006
	Underweight/ normal (<25kg/ m^2)	28 (12.9)	50 (26.6)	Reference	
	Missing	85 (39.2)	52 (27.7)	2.92 (1.64–5.20)	<0.001
High blood pressure	Yes	11 (5.1)	9 (4.8)	1.06 (0.43–2.62)	0.90
	No	206 (94.9)	179 (95.2)	Reference	
Diabetes	Yes	6 (2.8)	5 (2.7)	1.04 (0.31–3.47)	0.95
	No	211 (97.2)	183 (97.3)	Reference	
Heart disease	Yes	7 (3.2)	2 (1.1)	3.10 (0.64–15.11)	0.16
	No	210 (96.8)	186 (98.9)	Reference	
Stroke	Yes	1 (0.5)	1 (0.5)	0.87 (0.05–13.94)	0.92
	No	216 (99.5)	187 (99.5)	Reference	

LC = long COVID; OR = odds ratio; 95% CI = 95% confidence interval; BMI = body mass index.

Study participants with a BMI of ≥25kg/m^2 had over twice the risk of developing long COVID than those with a BMI of <25kg/m^2. Participants who did not report their height and/or weight had nearly a three times higher risk of developing long COVID compared with those with a BMI of <25kg/m^2. It was suggested that having pre-existing heart disease was associated with a higher likelihood of developing long COVID. However, this did not reach conventional levels of statistical significance. No other associations between socio-demographic variables and long COVID were identified in our crude analyses.

After adjusting for all explanatory variables shown in Table 1, there remained a strong positive association between BMI and the risk of long COVID. Participants with missing BMI data also appeared to have a higher risk than those with underweight/normal BMI (see Table 3). It was suggested that participants with pre-existing heart disease were more likely to develop long COVID than those who did not have heart disease. However, this did not reach conventional levels of statistical significance (see Table 3). When comparing very high BMI (≥30kg/m^2) to underweight/normal BMI, the association showed similar effects to those observed when comparing high BMI (≥25kg/m^2 to 30kg/m^2) to underweight/normal BMI (for "very high BMI': adjusted odds ratio [aOR] 2.26; 95% CI 1.17–4.39, and for "high BMI": aOR 2.43; 95% CI 1.29–4.58).

There was a significant degree of missing data in the BMI variable. Nearly 40% (n=85/217, 39.2%) of participants with long COVID did not report their height and/or weight in the survey. Participants who did not report their height and/or weight had a higher risk of developing long COVID than those who did report their height and weight (Appendix Table 1).

Most measures of socio-economic position were not related to missing BMI data (Appendix Table 2). However, there was weak evidence suggesting that participants who reported income struggle were more likely not to report their height and/or weight compared with those who reported no income struggle. Furthermore, participants who did not indicate their level of income struggle were significantly more likely not to report their

Table 3: The association between metabolic risk factors and long COVID (multivariable logistic regression model).

Variable	Category	*aOR (95% CI)	p-value
BMI	High BMI (≥25kg/m^2)	2.35 (1.33–4.17)	0.003
	Underweight/normal (<25kg/m^2)	Reference	
	Missing	5.46 (1.74–17.2)	0.004
High blood pressure	Yes	1.34 (0.50–3.60)	0.56
	No	Reference	
Diabetes	Yes	1.52 (0.41–5.62)	0.53
	No	Reference	
Heart disease	Yes	4.31 (0.80–23.3)	0.090
	No	Reference	
Stroke	Yes	1.02 (0.05–18.69)	0.99
	No	Reference	

aOR = adjusted odds ratio; 95% CI = 95% confidence interval; BMI = body mass index.
*Adjusted for age, gender, prioritised ethnicity, education, income struggle, overcrowding, pre-COVID disability, COVID-19 vaccine and COVID-related hospitalisation.

Table 4: Sensitivity analysis for BMI and the risk of long COVID.

	Treatment of missing BMI data	OR (95% CI)	p-value	*aOR (95% CI)	p-value
Scenario 1	Underweight/ normal/missing BMI	Reference		Reference	
	High BMI	1.09 (0.74–1.61)	0.66	1.73 (1.02–2.93)	0.042
Scenario 2	Underweight/ normal BMI	Reference		Reference	
	High/missing	2.45 (1.47–4.08)	0.001	2.53 (1.44–4.45)	0.001

BMI = body mass index; OR = odds ratio; 95% CI = 95% confidence interval; aOR = adjusted odds ratio.
*Adjusted for age, gender, prioritised ethnicity, education, income struggle, overcrowding, pre-COVID disability, COVID-19 vaccine and COVID-related hospitalisation.

Table 5: BMI and the risk of long COVID stratified by Māori/non-Māori.

Variable	Category	Māori (%)	OR (95% CI)	p-value	Non-Māori (%)	OR (95% CI)	p-value
BMI	High BMI	32 (52.5)	1.70 (0.25–11.59)	0.59	158 (45.9)	2.22 (1.25–3.93)	0.006
	Under-weight/ normal BMI	5 (8.2)	Reference		73 (21.2)	Reference	
	Missing	24 (39.3)	2.10 (0.29–14.98)	0.66	113 (32.9)	3.06 (1.66–5.64)	<0.001

BMI = body mass index; OR = odds ratio; 95% CI = 95% confidence interval.

height and/or weight than those who reported no income struggle.

The primary analyses presented above estimated the association between BMI and long COVID with missing BMI data treated as a separate category. We conducted a sensitivity analysis in which missing BMI data were recategorised with the underweight/normal BMI (<25kg/m^2) group (scenario one) and with the high BMI (≥25kg/m^2) group (scenario two); see Table 4. In the fully adjusted multivariable model, the most conservative estimate of risk between BMI and long COVID (scenario 1) found that participants with a BMI of ≥25kg/m^2 remained more likely to develop long COVID than those with a BMI of <25kg/m^2. The least conservative estimate of risk between BMI and long COVID (scenario 2) showed that participants with a high BMI had a higher risk of developing long COVID than those with an underweight/normal BMI. From these estimations, it appears that the association between BMI and long COVID is not explained by the degree of missing data in our study.

Sub-group analysis by Māori/non-Māori

We repeated the analyses stratified by Māori/non-Māori ethnicity. Over half (52.5%) of Māori were identified as having a high BMI compared with 45.9% of non-Māori (p=0.058) (see Table 5). When treating missing BMI data as a distinct category, among Māori no association was found between BMI and long COVID. Similarly, there was no evidence of an association among Māori who did not report their height and/or weight and long COVID. Among non-Māori, participants with a high BMI had over a two times higher likelihood of developing long COVID than those with an underweight/normal BMI. Similarly, non-Māori participants who did not report their height and/or weight had over a three times higher risk of developing long COVID compared with non-Māori with an underweight/normal BMI.

Using a formal test of interaction, there was no evidence to reject the null hypothesis that the effect of high BMI on long COVID differs between Māori and non-Māori (p=0.73).

Discussion

Our analyses demonstrate a strong association between high BMI and long COVID, but found no evidence of an association between other metabolic risk factors and long COVID. This finding suggests that the association between obesity and long COVID may be mediated by a mechanism other than the metabolic pathways that we measured, although the small numbers of people with diagnosed metabolic illnesses may have precluded our ability to detect real results. As the pathophysiology of long COVID is still poorly understood, this study provides epidemiological evidence to strengthen the accumulating biomedical evidence of the immune-metabolic disruption evident in people with long COVID.

To our knowledge, this is the only study in Aotearoa New Zealand to investigate the association between metabolic risk factors and long COVID. Rates of metabolic disease and obesity are high in Aotearoa New Zealand, particularly among Māori and Pacific populations; being able to report associations among Māori is an important strength of this study.[7,23,24]

The definition of long COVID used within this research was based on self-reported ongoing symptoms for 3 months or longer. As recognised in other international literature, there is no unified consensus on the definition of long COVID, especially concerning the duration of persistent symptoms, which span from 4 to 12 weeks following COVID-19 infection.[2] This limitation impedes the ability to compare findings with other studies. Moreover, as reported in the qualitative analysis of *Ngā Kawekawe o Mate Korona*, many interviewees, disproportionately Māori and Pacific peoples, attributed their ongoing symptoms to underlying conditions.[6] This difficulty in understanding and interpreting health information may contribute to an under-counting of long COVID cases among Māori and Pacific peoples (i.e., the misclassification of outcome). Similarly, considering the well-described barriers to healthcare access and experiences of institutional racism within Aotearoa New Zealand's health system,[25] it is likely that self-reported diagnoses of metabolic illnesses are disproportionately under-reported by Māori and Pacific peoples. Both biases of under-reporting and under-counting may impede our ability to identify associations between metabolic factors and long COVID.

Moreover, the 12% response rate could have resulted in a biased estimate of long COVID prevalence. In particular, the prevalence of long COVID could be over-estimated as this was the first national research conducted in this area, and people with a "new" condition were more likely to take part. The estimated prevalence of long COVID in our study ranged from 2.5% (based on a denominator of all eligible people) to 21.9% (based on a denominator of all respondents). While there is no national estimate for long COVID prevalence, international studies suggest a range between 4 and 14%,[4,5] which is consistent with our findings.

While response bias likely over-inflates the prevalence estimate, it is unlikely to have biased the association between high BMI and long COVID. Since the survey was available to anyone who had COVID-19 prior to December 2021, differential participation by both BMI and long COVID status is unlikely to have occurred. Although ORs are an appropriate measure of relative risk when the outcome is rare, the high prevalence of long COVID in our sample means that the use of logistic regression to estimate ORs may have inflated the estimated association.

Although widely used in population-based studies, BMI is limited as an accurate measure of obesity, with differential associations with obesity across genders, ages and ethnicities.[26] This is due to BMI not discriminating between levels of muscle mass, bone density, overall body composition and metabolism, alongside other risk factors, such as social and environmental determinants.[26] In the context of Aotearoa New Zealand, Māori and Pacific peoples often have higher lean body mass and lower fat mass than non-Māori, non-Pacific individuals at the same value of BMI.[27] The relatively few cases of long COVID among Māori means that stratified analyses are underpowered to detect real effects between Māori and non-Māori. Although there were high levels of missing BMI data in the study, the observation that both scenarios of our sensitivity analysis found significant associations between high BMI and long COVID strengthens our confidence in the accuracy of our interpretation.

The findings of this study are consistent with previous evidence. A cross-sectional study of 1,056 general practices in Germany reported a linear association between BMI and the risk of developing long COVID.[11] That study also reported an association between BMIs of >25kg/m^2 and long COVID, with this association present for females and no clear evidence of an association for males.[11] A matched cohort study of non-hospitalised adults reported that a BMI between 25 and 30kg/m^2 was associated with a slight risk increase in developing long COVID compared with a BMI between 18 and 25kg/m^2 (adjusted hazard ratio 1.07; 95% CI 1.04–1.10).[13] More recently, a systematic review and meta-analysis of 16 studies investigating obesity found that a BMI of ≥30kg/m^2 was statistically associated with long COVID.[14] At the time of this study, the population in Aotearoa New Zealand had high vaccination rates compared with the rest of the world, highlighting the importance of adding our findings to the international literature. However, the magnitude of the associations between BMI and long COVID that we report are higher than the estimates in previous literature. The reasons for this remain unclear; we emphasise that our results should be interpreted with caution.

In Aotearoa New Zealand, over two-thirds of individuals were classified as overweight or obese, with a BMI of >25kg/m^2, in 2023–2024.[23] There are significant differences in the prevalence of obesity among ethnic groups, with Māori and Pacific peoples having disproportionately higher rates compared with individuals of European/Other and Asian ethnicities.[23] These inequities begin early in life and are intergenerational. It

has been suggested that prolonged exposure to obesity throughout one's life could be associated with a higher risk of developing long COVID.[28] These observations suggest a mechanism through which the ongoing impacts of COVID-19 could exacerbate existing health inequities.

Although causal inferences cannot be made from observational data such as our investigation, this study provides epidemiological evidence to support our understanding of long COVID as an immuno-metabolic disease. Associations between nutritional status and immune dysfunction have been widely documented.[29] Obesity is associated with chronic, low-grade systemic inflammation, which hinders an individual's effective and timely immune response to an infectious disease like COVID-19,[28,29] and, as suggested in our study and others, a higher likelihood of developing long COVID.[14] These findings encourage further investigation exploring the link between immune dysfunction, obesity and long COVID and open possibilities of avenues for therapeutic advances.

Conclusion

In summary, we found that high BMI, but not other metabolic illnesses or risk factors, was associated with a higher risk of long COVID. This highlights the need for long COVID to be considered as an immune-metabolic disease and opens possibilities of avenues for therapeutic advances. Future research should explore the associations between immune function, obesity and long COVID to expand on our findings.

COMPETING INTERESTS
Mona Jeffreys is a Board Member of ME Support.

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Appendix

Appendix Table 1: The risk of long COVID in participants with missing compared with non-missing BMI.

Variable	Category	LC (%) n=217	No LC (%) n=188	OR (95% CI)	p-value
Missingness of BMI	Missing variables	85 (39.2)	52 (27.7)	1.68 (1.12–2.56)	0.015
	Not missing	132 (60.8)	136 (72.3)	Reference	

LC = long COVID; OR = odds ratio; 95% CI = 95% confidence interval; BMI = body mass index.

Appendix Table 2: Determinants of missingness in BMI.

Variable	Category	OR (95% CI)	p-value
Age	15–24	1.27 (0.64–2.15)	0.50
	25–44	Reference	
	45–64	0.75 (0.47–1.20)	0.23
	65+	0.49 (0.22–1.10)	0.09
Gender	Male	Reference	
	Female	1.05 (0.67–1.65)	0.83
Ethnicity	Māori	1.38 (0.78–2.44)	0.26
	Pacific peoples	1.07 (0.39–2.93)	0.90
	Asian	1.78 (0.74–4.26)	0.20
	Other	Reference	
Education	School	0.99 (0.59–1.67)	0.98
	Post-school	0.64 (0.37–1.11)	0.11
	University	Reference	
Income struggle	Strongly agree/agree	2.41 (0.98–5.94)	0.06
	Neither agree nor disagree	0.80 (0.22–2.92)	0.74
	Disagree/strongly disagree	Reference	
	Missing	87.20 (40.50–187.81)	<0.001
Household crowding	Overcrowding	1.68 (0.71–3.99)	0.24
	None	Reference	
Pre-COVID disability	Pre-COVID disabled	1.45 (0.72–2.90)	0.30
	Non-disabled	Reference	

BMI = body mass index; OR = odds ratio; 95% CI = 95% confidence interval.