Detailed statistical methods

Interrupted time series models

An interrupted time series model for the number of services delivered at time t, Y_t, can be modelled using the following form:

$$Y_t \sim \text{Poisson}(\mu_t)$$

$$\log(\mu_t) = \beta_0 + \beta_1 t + \beta_2 COVID_t + \beta_3 Quarter_t + \log(ERP_t)$$

In this model, we evaluate the interrupting effect of COVID-19 during the year 2020 with the term $COVID_t$ ($COVID_t = 1$ for 2020 and $COVID_t = 0$ otherwise). This model also controls for a linear long-term trend (the year quarter since the start of the time series, $t = 2011, 2011.25, 2011.5$ ...) and seasonality (categorical variable for four quarters of the year, $Quarter = 1^{st}, 2^{nd}, 3^{rd}$ and 4^{th}). The estimated residential population at time t is used as an offset variable (ERP_t).

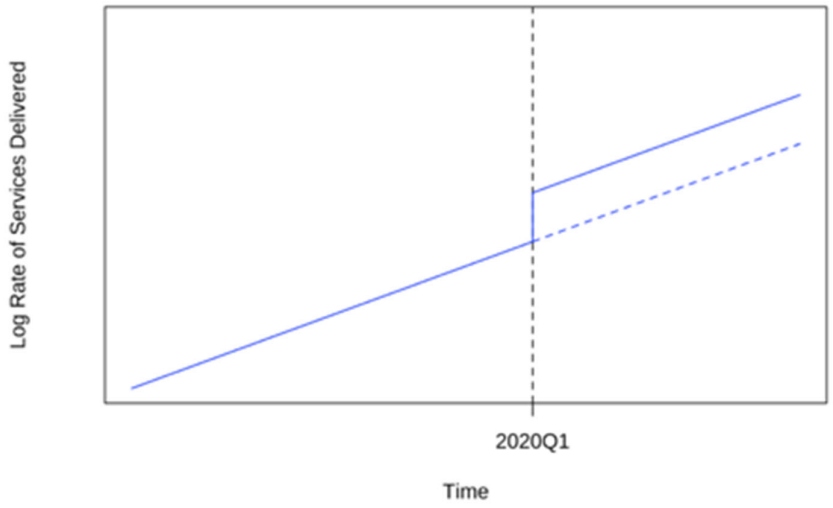
As overdispersion (variance exceeds the mean) is presented in almost all series, the quasi-Poisson model was used instead of the standard Poisson regression. The quasi-Poisson model is a generalized linear model which applies a quasi-likelihood relaxing the equal model mean and variance assumption (1), through the variance formula:

$$Var(Y_t) = \phi \mu_t$$

ϕ is the dispersion parameter ($\phi > 1$ when there is over-dispersion). Whilst the coefficient estimates remain the same, the updated variance formula provides more accurate and conservative standard errors for these estimates.

Strong temporal residual autocorrelations were found in about 12% of time series, using the Box-Pierce test (2), which mostly related to localised nonlinearities (departing from linearity for a few continuous data points) driven by unobserved factors such as changes in services availability. When not controlled, the residual autocorrelations may cause an underestimation of variance of estimated coefficients (3). In most of these series, strong autocorrelation was only found at lag 1 when inspecting with autocorrelation function (ACF) and a partial autocorrelation function (PACF) plot. As a result, the autoregressive correlation structure model at lag 1, $AR(1)$, was in models presented with strong evidence of residual autocorrelations (p-value <0.05 for Box-Pierce test).

The β_2 parameter models the single level change in 2020 due to the interruption of the COVID-19 pandemic in Australia. This impact model is depicted in an illustration Figure below.



This model was selected to model the average change in 2020 compared to the historical trend. Whilst there is reason to believe a possible change of slope since 2020, it is impractical to estimate both a change in level and slope with the small number of observations since 2020.

Meta-analysis

The COVID-19 interruption effect coefficient, β_2 ,estimated for all SA3s were pooled using random effects meta-analysis for each population. Results were expressed as the exponential of the pooled coefficient, which represents RR. Restricted maximum likelihood (REML) estimation was used to generate the coefficient estimates in order to produce unbiased estimates of the variance and covariance parameters that make up the AR(1) correlation structure (4). Test statistics for the meta-analysis were calculated using the Knapp-Hartung method, which has been shown to produce lower type I error rates when there are many coefficient estimates (SA3s) with unequal population sizes and between-study heterogeneity, as is evident in this study (5).

Meta-regression

A similar model is used for meta-regression to establish its relationships with location (metropolitan vs. regional), level of socio-economic advantage and disadvantage (IRSAD score), and state (Victoria vs. the rest of Australia). Letting $\hat{\beta}_2^i$ be the interruption effect estimate for SA3 i for a specific population the meta-regression model is given by:

$$\hat{\beta}_2^i = \alpha_0 + \alpha_1 Regional_i + \alpha_2 IRSAD_i + \alpha_3 Victoria_i + u_i + \epsilon_i$$

The covariates $Regional_i$ and $Victoria_i$ are binary variables with baselines "Metropolitan" and "Rest of Australia" respectively. $IRSAD_i$ represents the IRSAD score for SA3 i centred on the Australian mean IRSAD score and expressed per 100 units. The coefficients satisfy $\alpha_0, \alpha_1, \alpha_2, \alpha_3 \in \mathbb{R}$. The term u_i represents variability due to differences (heterogeneity) in true pandemic effects between SA3s. The term ϵ_i measures the sampling error – the variability in that SA3 and subgroup's interruption effect due to not being able to sample all relevant 12-25-year-olds perfectly accurately or at all.

Estimation methods

Quasi-Poisson AR(1) regression models were estimated using penalised quasilikelihood (PQL) with the "glmmPQL" function from the "MASS" library. As there were limited data points in each series, maximum likelihood estimation may suffer from small sample bias with complicated models (6). In this case, penalised maximum likelihood estimation can be a better choice (6). Sensitivity analyses were also conducted using "glm" function in "stats" library without AR(1) autocorrelation structure. Meta-analysis and meta-regression models were estimated using the "rma" function from the "metafor" library. All analysis codes can be found on the GitHub repository: https://carolinexgao.github.io/MBS_COVID

Supplementary tables and figures

Figure S1

Distribution of IRSAD scores (A: cumulative distribution and B: histogram) across 331 SA3 areas included in the study (A) cumulative distribution (B) histogram

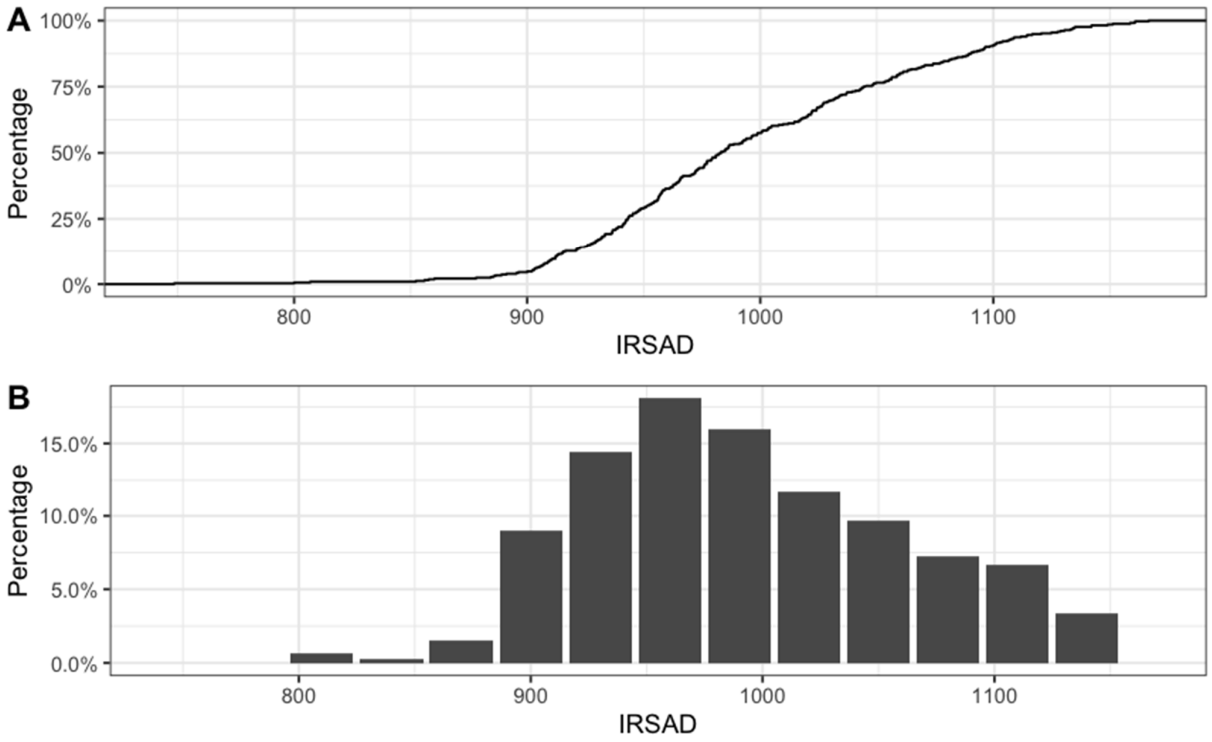


Table S1

Medicare Benefit Schedule (MBS) mental health related items

MBS Group	Group Description	Items
A06	Group therapy	170, 171, 172
A07	Acupuncture and non-specialist practitioner items*	221, 222, 223, 272, 276, 277, 279, 281, 282, 283, 285, 286, 287, 371, 372, 894, 896, 898
A08	Consultant psychiatrist attendances to which no other item applies	288, 289, 291, 293, 296, 297, 299, 300, 302, 304, 306, 308, 310, 312, 314, 316, 318, 319, 320, 322, 324, 326, 328, 330, 332, 334, 336, 338, 342, 344, 346, 348, 350, 352, 353, 355, 356, 357, 358, 359, 361, 364, 366, 367, 369, 370
A15	GP management plans, team care arrangements, multidisciplinary care plans	855, 857, 858, 861, 864, 866
A30	Medical practitioner (including a general practitioner, specialist or consultant physician) telehealth attendances	2121, 2150, 2196
A20	GP mental health treatment	2700, 2701, 2702, 2710, 2712, 2713, 2715, 2717, 2719, 2721, 2723, 2725, 2727, 2729, 2731
M03	Allied health services	10956, 10968
T01	Miscellaneous therapeutic procedures	14224
M06	Psychological therapy services	80000, 80001, 80005, 80010, 80011, 80015, 80020, 80021
M07	Focused psychological strategies (allied mental health)	80100, 80101, 80105, 80110, 80111, 80115, 80120, 80121, 80125, 80126, 80130, 80135, 80136, 80140, 80145, 80146, 80150, 80151, 80155, 80160, 80161, 80165, 80170, 80171
M11	Allied health services for indigenous Australians who have had a health check	81325, 81355
M10	Autism, pervasive developmental disorder and disability services	82000, 82005, 82010, 82015, 82020, 82025, 82030, 82035
M16	Eating disorders services	82350, 82351, 82352, 82353, 82354, 82355, 82356, 82357, 82358, 82359, 82360, 82361, 82362, 82363, 82364, 82365, 82366, 82367, 82368, 82369, 82370, 82371, 82372, 82373, 82374, 82375, 82376, 82377, 82378, 82379, 82380, 82381, 82382, 82383
A36	Eating disorder services	90250, 90251, 90252, 90253, 90254, 90255, 90256, 90257, 90260, 90261, 90262, 90263, 90264, 90265, 90266, 90267, 90268, 90269, 90271, 90272, 90273, 90274, 90275, 90276, 90277, 90278, 90279, 90280, 90281, 90282
M17	Bushfire recovery access initiative - psychologist services and allied health focused psychological strategies	91000, 91001, 91005, 91010, 91011, 91015, 91100, 91101, 91105, 91110, 91111, 91115, 91125, 91126, 91130, 91135, 91136, 91140, 91150, 91151, 91155, 91160, 91161, 91165
M18	COVID-19 allied health telehealth services	91166, 91167, 91169, 91170, 91172, 91173, 91175, 91176, 91181, 91182, 91183, 91184, 91185, 91186, 91187, 91188, 93032, 93033, 93035, 93036, 93040, 93041, 93043, 93044, 93074, 93076, 93079, 93084, 93087, 93092, 93095, 93100, 93103, 93108, 93110, 93113, 93118, 93121, 93126, 93129, 93134, 93137

MBS Group	Group Description	Items
A39	Bushfire recovery access initiative - GP and medical practitioner focused psychological strategies	91283, 91285, 91286, 91287, 91371, 91372, 91721, 91723, 91725, 91727, 91729, 91731
A40	COVID-19 services	91818, 91819, 91820, 91821, 91827, 91828, 91829, 91830, 91831, 91837, 91838, 91839, 91840, 91841, 91842, 91843, 91844, 91845, 92112, 92113, 92114, 92115, 92116, 92117, 92118, 92119, 92120, 92121, 92122, 92123, 92124, 92125, 92126, 92127, 92128, 92129, 92130, 92131, 92132, 92133, 92134, 92135, 92146, 92147, 92148, 92149, 92150, 92151, 92152, 92153, 92154, 92155, 92156, 92157, 92158, 92159, 92160, 92161, 92162, 92163, 92166, 92167, 92170, 92171, 92172, 92173, 92176, 92177, 92178, 92179, 92182, 92184, 92186, 92188, 92194, 92196, 92198, 92200, 92434, 92435, 92436, 92437, 92455, 92456, 92457, 92458, 92459, 92460, 92474, 92475, 92476, 92477, 92495, 92496, 92497, 92498, 92499, 92500
A41	COVID-19 additional focused psychological strategies	93300, 93301, 93302, 93303, 93304, 93305, 93306, 93307, 93308, 93309, 93310, 93311
M25	COVID-19 additional psychological therapy services	93330, 93331, 93332, 93333, 93334, 93335
M26	COVID-19 additional focused psychological strategies (allied mental health)	93350, 93351, 93352, 93353, 93354, 93355, 93356, 93357, 93358, 93359, 93360, 93361, 93362, 93363, 93364, 93365, 93366, 93367

*Non-Specialist Practitioner Items for mental health services from the A7 Group were included, for example, Medical Practitioner Provision of Focussed Psychological Strategies (Items 283 to 287, 371 and 372).

Figure S2

Boxplot of SA3 level quarterly MBS mental health service use rates among young people (age 12-25) in 2019 and 2020.

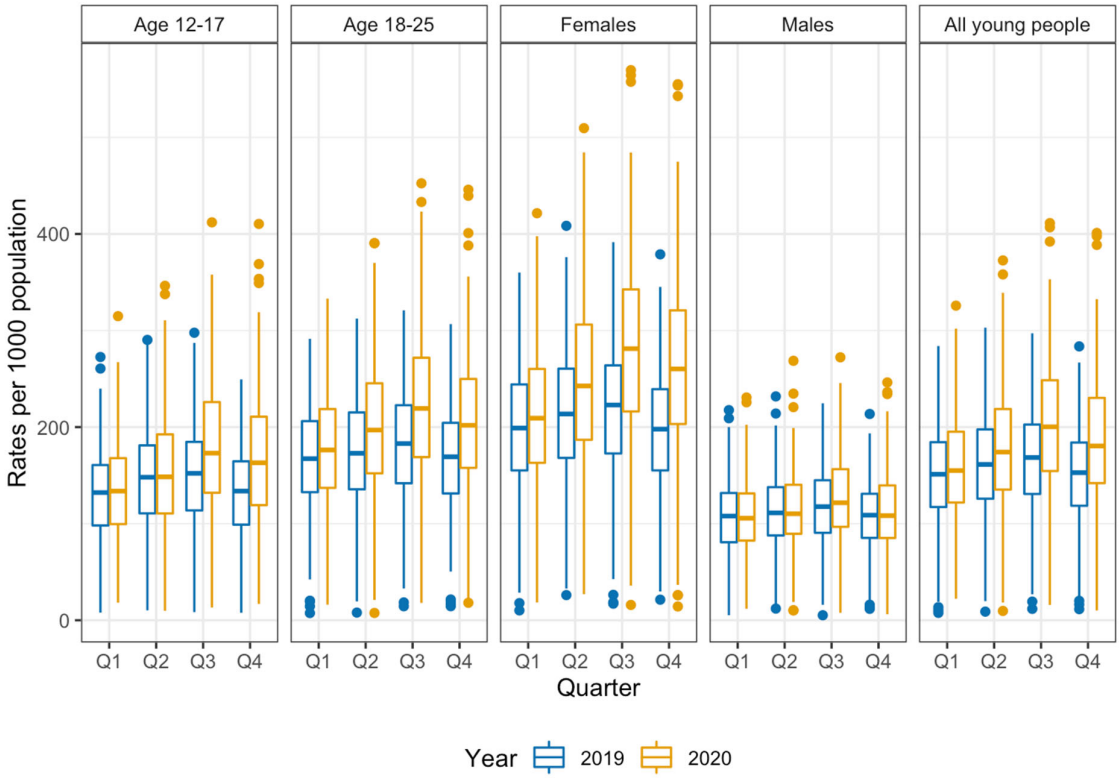


Figure S3

Geospatial distribution of annual MBS mental health service use rate per 1000 population among young people (age 12-25) in 2020 by SA3.

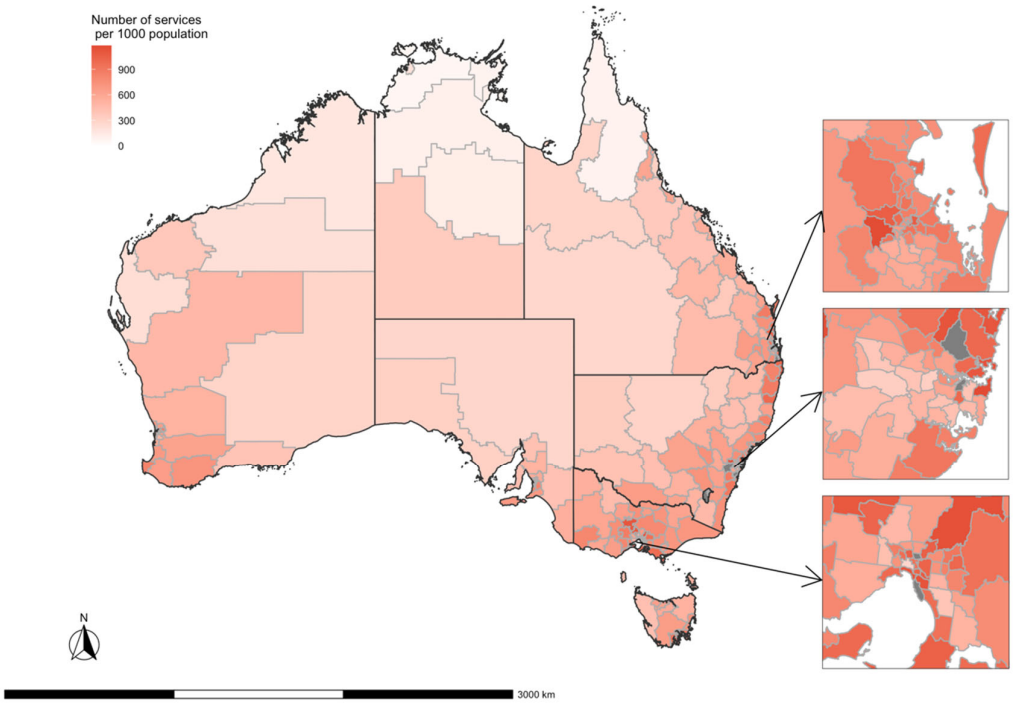


Figure S4

Trends of MBS mental health quarterly service use rates (per 1000 population) among young people (age 12-25) for individual SA3 area. The superimposed red line indicates the mean rates across all SA3 areas.

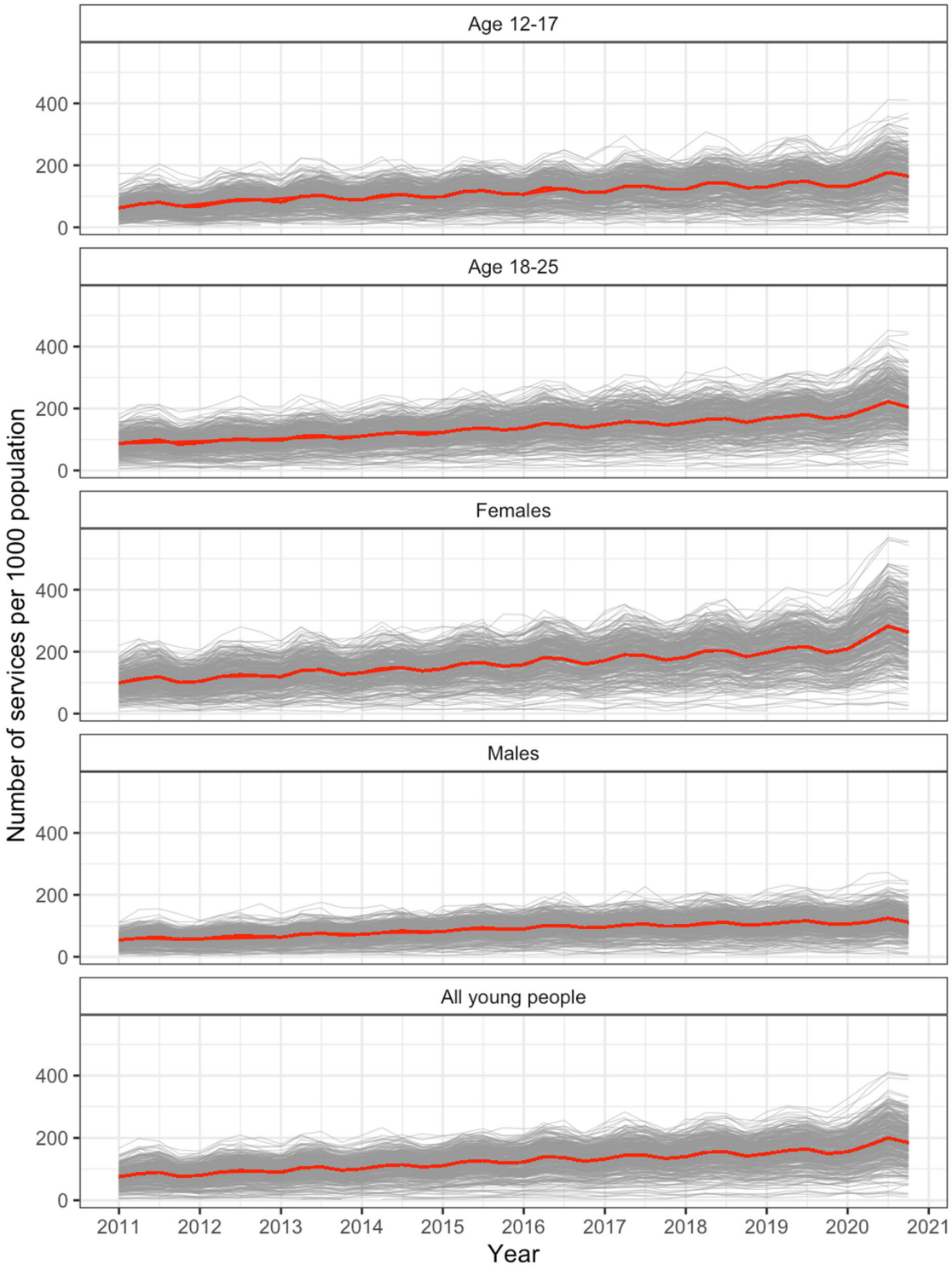


Table S2

Distribution (median and interquartile range: Q1-Q3) of MBS service use rate (services per 1000 population per year across all SA3) by state in the pre-pandemic year (2019) and pandemic year (2020) for all young people (age 12-25), and age and sex subgroups.

Characteristic	State	2019	2020	Percentage increase
Age 12-17	Victoria	636 (508, 733)	655 (511, 855)	9% (2%, 17%)
	Other	553 (413, 680)	619 (457, 783)	13% (5%, 21%)
Age 18-25	Victoria	765 (610, 870)	886 (739, 1,071)	21% (15%, 26%)
	Other	682 (525, 839)	761 (595, 972)	14% (9%, 20%)
Females	Victoria	921 (751, 1,089)	1,155 (933, 1,405)	26% (16%, 31%)
	Other	813 (639, 999)	963 (744, 1,205)	19% (13%, 27%)
Males	Victoria	474 (405, 550)	465 (408, 596)	3% (-3%, 8%)
	Other	435 (335, 536)	439 (344, 556)	3% (-3%, 9%)
All young people	Victoria	695 (560, 817)	796 (659, 984)	17% (10%, 22%)
	Other	612 (482, 757)	685 (540, 874)	13% (8%, 20%)

Figure S5

Comparison between estimated RRs for COVID-19 in SA3s (A) in Victoria compared with other states and (B) in metropolitan SA3s compared regional SA3s. Note: data from four SA3 areas from Northern Territory were excluded as outliers.

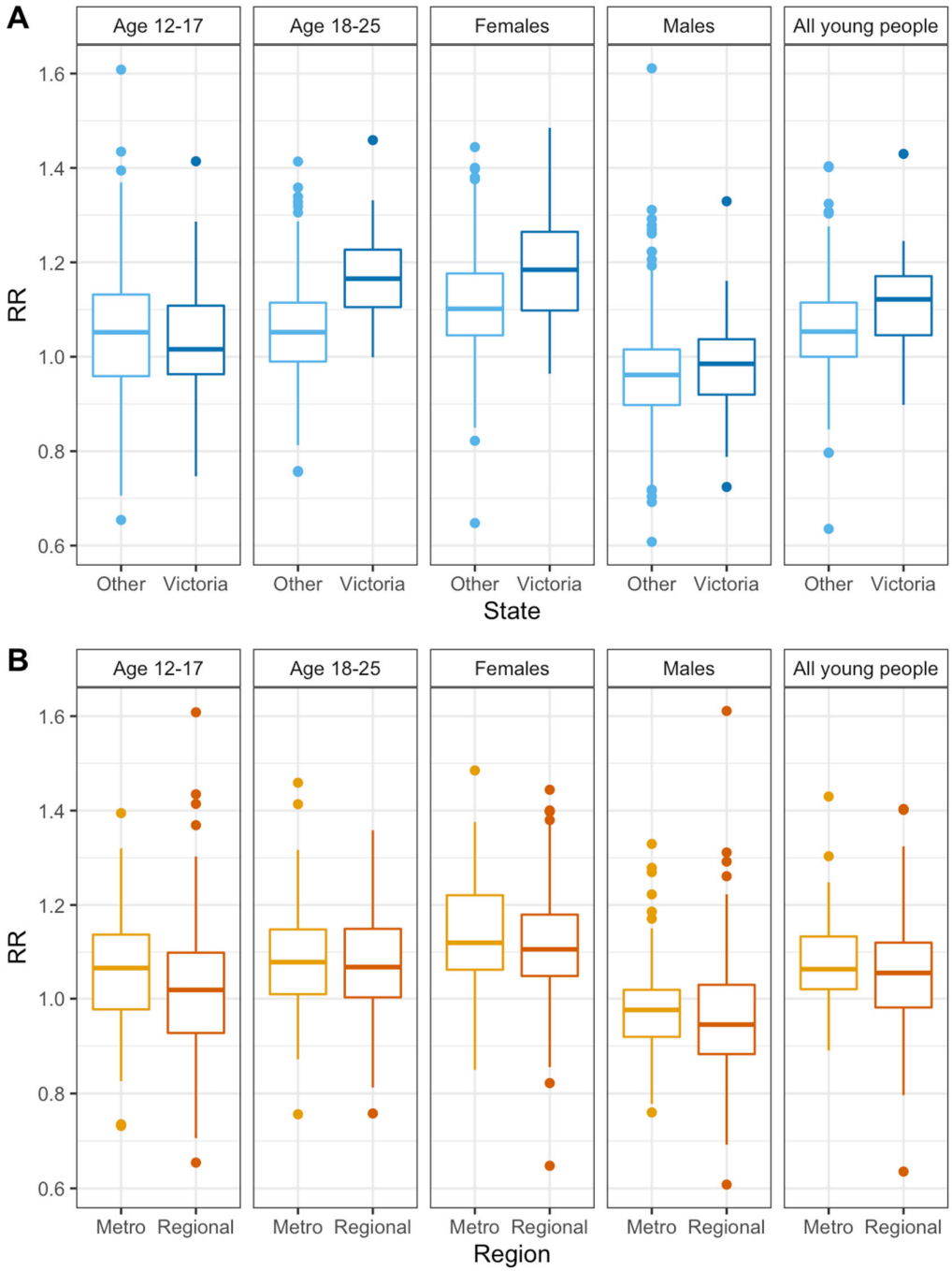


Figure S6

Sensitivity analysis of pooled COVID-19 interruption effect estimated from interrupted time series models for individual SA3 areas (using random effects meta-analysis) by different subgroups ignoring temporal autocorrelation (excluding AR1).

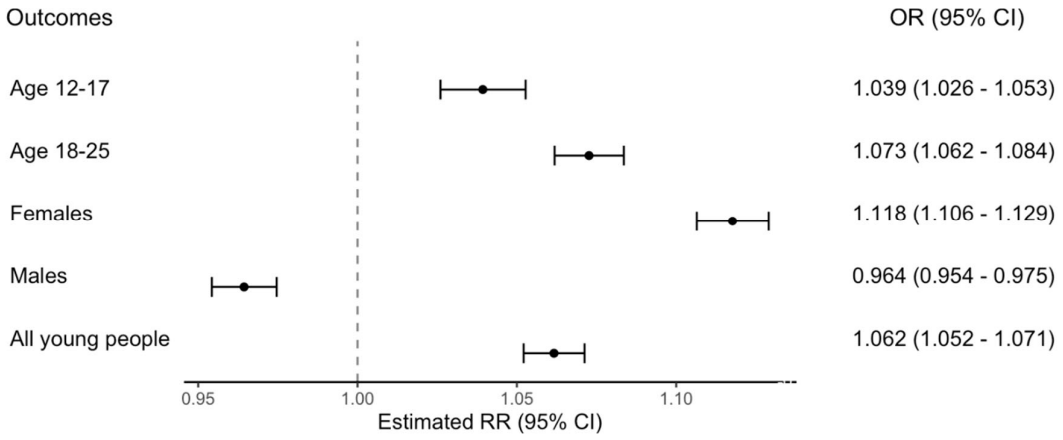
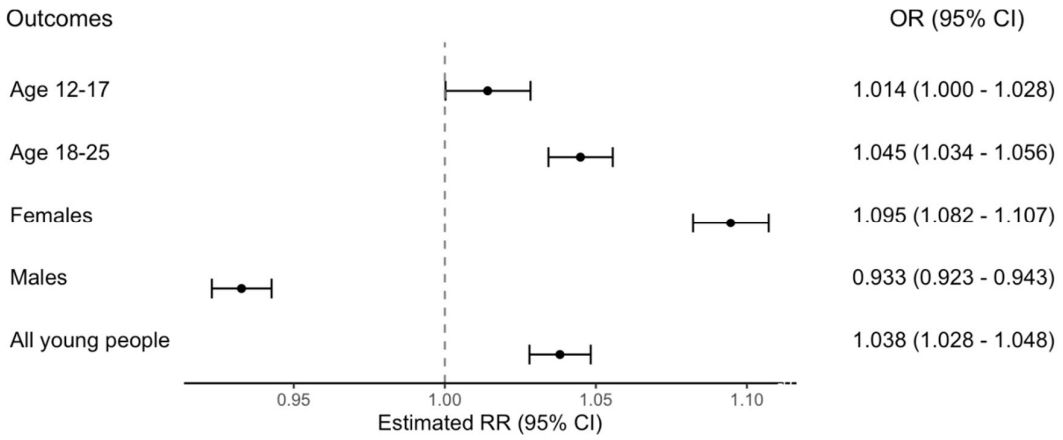


Figure S7

Sensitivity analysis of pooled COVID-19 interruption effect estimated from interrupted time series models for individual SA3 areas (random effect meta-analysis) by different subgroups using data from 2011 to 2020.



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