## The rate and influencing factors of SARS-CoV-2 Reinfection: systematic review and meta-analysis

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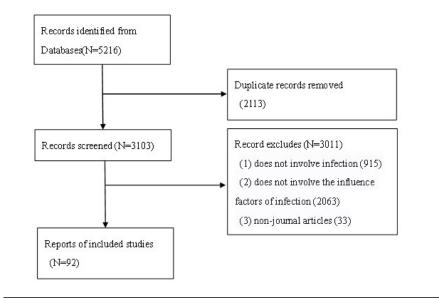
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## Abstract

Background: Understanding the SARS-COV-2 reinfection rate and its potential influencing factors is essential for further improvement and development of prevention and control strategies and measures to reduce the reinfection rate of SARS-CoV-2. This study aimed to quantitatively summarize the evidence of current reinfection studies. Methods: We reviewed all English studies published up to Dec 4, 2022. Information extracted from each selected articles and quality assessment of these articles was used to evaluate the risk for bias in studies. The meta-analysis was performed to examine the rate and influencing factors of SARS-CoV-2 reinfection and protective effect of primary infection on reinfection in our study. Sources of heterogeneity were identified using a subgroup analysis defined by the minimum time interval of days to reinfection and variant strains. Results: The weighted pooled rate of reinfection for SARS-CoV-2 was 1.08% ([95% CI, 0.77%-1.52%], I2 = 100%, P < 0.001). Subgroup-analysis of the minimum time interval definition for reinfection showed that rates of reinfection are 0.71%, 0.75%, 1.46% and 1.62% in less than 90 days, greater than 90 days, unknown groups, respectively and 0.64%, 1.8%, 3.08%, 0.95% in Alpha, Delta, Omicron, unknown groups. The weighted pooled RR value of the protective effect of primary infection on reinfection rate of SARS-CoV-2 is relatively low and appears to be on the rise as duration from the first infection to the second infection and the novel coronavirus strain mutates.

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14/13857         #           8/4901         #           749         #           58811         119266           1959234         27758           362650         2625           190         4976           491         1572           350         999933           2010         131773           335         309           2210         210	2.96 [2.95, 2.97] 1.62 [3.63, 1.71 1.162 [9.41; 1.41, 3. 1.072 [0.65; 0.79 0.61 [0.67; 0.66 3.38 [3.81; 3.85 0.05 [0.03; 0.06 3.80 [3.41; 3.85 0.00 [0.00; 1.92 2.33 [1.93, 2.79 1.83 [0.44; 3.45 2.54 [1.82; 3.45 1.144 [0.31; 2.59 0.21 [0.18; 0.24 1.142 [0.18; 0.24 1.142 [0.18] [2.41] 1.143 [2.30]
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749	$\begin{array}{c} 11.62  [9.41; 14.13 \\ 0.72  [0.65, 0.79 \\ 0.61  [0.57, 0.66 \\ 3.83  [3.81; 3.85 \\ 0.05  [0.33, 0.06 \\ 3.80  [3.74; 3.87 \\ 5.94  [5.07; 6.62 \\ 0.00  [0.00; 1.92 \\ 2.33  [1.93, 2.79 \\ 1.83  [0.84; 3.45 \\ 2.54  [1.82; 3.45 \\ 1.14  [0.31; 2.90 \\ 0.21  [0.18; 0.24 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36 \\ 1.64  [1.13; 2.36  [1.36] \\ 1.64  [1.13; 2.36  [1.36] \\ 1.64  [1.13; 2.36  [1.36] \\ 1.64  [1.32; 2.36  [1.36] \\ 1.64  [1.32; 2.36  [1.36] \\ 1.64  [1.32; 2.36  [1.36] \\ 1.64  [1.32; 2.36  [1.36] \\ 1.64  [1.32; 2.36  [1.36] \\ 1.64  [1.32; 2.36  [1.36] \\ 1.64  [1.32; 2.36  [1.36] \\ 1.64  [1.32; 2.36  [1.36] \\ 1.64$
58811 119266 559234 27758 362850 2825 190 4978 491 1572 350 99933 2010 131773 825 309 82010	0.72 [0.65; 0.79 0.61 [0.57; 0.66 3.83 [3.81; 3.85 0.05 [0.03; 0.08 3.80 [3.74; 3.87 5.94 [5.07; 6.92 0.00 [0.00; 1.92 2.33 [1.93; 2.79 1.83 [0.84; 3.45 2.54 [1.82; 3.45 1.14 [0.31; 2.90 0.21 [0.18; 0.24 1.64 [1.13, 2.30
119266 586234 27758 382285 190 4977 491 1572 355 99993 2010 131773 835 309 835 2010	0.61 0.57,066 3.83 (3.81;3.85 0.05 (0.03;0.06 3.80 (3.74;3.87 5.94 (5.07;6.92 0.00 (0.00;1.92 2.33 (1.93;2.79 1.83 (0.84;3.45 1.14 (0.31;2.30 0.21 (0.18;0.24 1.64 (1.13;2.30
569234 27758 362650 2625 4970 4977 4977 1572 2010 131773 8255 300 2010	3.83 [3.81; 3.85 0.05 [0.03; 0.08 3.80 [3.74; 3.87 5.94 [5.07; 6.92 0.00 [0.00; 1.92 2.33 [1.93; 2.79 1.83 [0.84; 3.45 1.14 [0.31; 2.90 0.21 [0.18; 0.24 1.64 [1.13; 2.30
27758 362255 190 497 491 1572 355 99993 2010 131773 835 309 2010	0.05 [0.03; 0.08 3.80 [3.74; 3.87 5.94 [5.07; 6.92 0.00 [0.00; 1.92 2.33 [1.93; 2.79 1.83 [0.84; 3.45 2.54 [1.82; 3.45 1.14 [0.31; 2.90 0.21 [0.18; 0.24 1.64 [1.13; 2.30
362650 2625 4978 4978 491 1572 350 99993 2010 131773 825 309 2010	3.80 [3.74; 3.87 5.94 [5.07; 6.92 0.00 [0.00; 1.92 2.33 [1.93; 2.79 1.83 [0.84; 3.45 2.54 [1.82; 3.45 1.14 [0.31; 2.90 0.21 [0.18; 0.24 1.64 [1.13; 2.30
2625 190 497 350 99993 2010 131773 835 300 835 2010	5.94 [5.07; 6.92 0.00 [0.00; 1.92 2.33 [1.93; 2.79 1.83 [0.84; 3.45 2.54 [1.82; 3.45 1.14 [0.31; 2.90 0.21 [0.18; 0.24 1.64 [1.13; 2.30
190 4978 4978 350 99993 2010 131773 825 309 210	0.00 [0.00; 1.92 2.33 [1.93; 2.79 1.83 [0.84; 3.45 2.54 [1.82; 3.45 1.14 [0.31; 2.90 0.21 [0.18; 0.24 1.64 [1.13; 2.30
4978 491 1572 350 99993 2010 131773 835 309 210	2.33 [1.93; 2.79 1.83 [0.84; 3.45 2.54 [1.82; 3.45 1.14 [0.31; 2.90 0.21 [0.18; 0.24 1.64 [1.13; 2.30
491 1572 350 2010 131773 835 309 210	1.83 [0.84; 3.45 2.54 [1.82; 3.45 1.14 [0.31; 2.90 0.21 [0.18; 0.24 1.64 [1.13; 2.30
1572 350 99993 2010 131773 835 309 210	2.54 [1.82; 3.45 1.14 [0.31; 2.90 0.21 [0.18; 0.24 1.64 [1.13; 2.30
350 99993 2010 131773 835 309 210	1.14 [0.31; 2.90 0.21 [0.18; 0.24 1.64 [1.13; 2.30
99993 2010 131773 835 309 210	0.21 [0.18; 0.24 1.64 [1.13; 2.30
2010 131773 835 309	1.64 [1.13; 2.30
131773 835 309 210	1.64 [1.13; 2.30
835 309	0.19 [0.17:0.22
309 <del>+</del> 210 <del>+</del>	
210 🗮	0.60 [ 0.19; 1.39
	4.53 [ 2.50; 7.49
	2.38 [ 0.78; 5.47
167	27.54 [20.93; 34.98
6	16.67 [ 0.42; 64.12
88	1.14 [ 0.03; 6.17
796	0.38 [ 0.08; 1.10
393	0.25 [0.01; 1.41
569	1.05 [ 0.39; 2.28
12272	0.60 [ 0.47; 0.76
688418	0.34 [ 0.33; 0.35
174 —	18.97 [13.43; 25.59
32607	0.08 [ 0.05; 0.12
62250	0.20 [ 0.17; 0.24
656	3.51 [2.24; 5.21
15687	0.25 [ 0.18; 0.35
9962	0.44 [ 0.32; 0.59
111239	20.55 [20.31; 20.78
9488 🛄	2.21 [ 1.93; 2.53
54233	2.27 [ 2.14; 2.40
1355 🔲	2.36 [ 1.62; 3.32
258935	1.09 [ 1.05; 1.13
41647	1.42 [1.31; 1.54
7173	0.33 [0.21; 0.50
11536	11.50 [10.93; 12.10
6014	0.02 [ 0.00; 0.09
349827	0.74 [0.71; 0.77]
58811	0.72 [ 0.65; 0.79
130855	0.35 [ 0.34; 0.35
218242	2.10 [2.04; 2.16
2013	1.09 [0.69; 1.65
784617	1.97 [ 1.95; 1.99
688418	0.34 [ 0.33; 0.35
749 🗰	11.62 [ 9.41; 14.13
408 📖	1.47 [ 0.54; 3.17
55338	0.38 [0.33; 0.43
556750	0.80 [ 0.78; 0.82
755 🛨	16.16 [13.60; 18.98
600000	0.68 [0.66; 0.71
12272	0.60 [0.47; 0.76
1388 🔛	5.26 [4.14; 6.57
569	1.05 [ 0.39; 2.28
335117	4.69 [ 4.62; 4.76
115	20.00 [13.12; 28.48
1014	4 04 [2 92: 5 45
3545	28.41 [26.93: 29.92
5459	0.24 [0.13; 0.41
860054	0.36 [ 0.36; 0.37
45832	36.84 [36.39; 37.28
	7.53 [ 3.82; 13.08
	0.05 [ 0.03; 0.08
	3.52 [ 3.34; 3.72
	5.94 [5.07; 6.92
2625	0.21 [0.14; 0.30
	0.2.1 [0.14, 0.30
2625 14320	1.08 [0.77; 1.52
3	3860054 45832 146 27758 35692 2625

Study	Events	Total	Events per 100 observations	Events 95%-4
Group = <90		1		
Sachin Dhumal 2022	6	408		1.47 [0.54; 3.1
Mostafa Salehi-Vaziri 2021	5	1492		0.34 [0.11; 0.7
Johan Ringlander 2021	1	6014		0.02 [ 0.00; 0.0
Laith J. Abu-Raddad3 2021	243	15808		1.54 [1.35; 1.7
Efrén Murillo Zamora 2021	210			0.21 [0.18; 0.2
Murillo-Zamora, E. 2021	258	100432		0.26 [0.23; 0.2
Emilie Finch 2022	14	309 🗯		4.53 [2.50; 7.4
Hussein, N. R. 2021	34	5609		0.61 [ 0.42; 0.8
Benjamin Davido 2021	5	236		2.12 [ 0.69; 4.8
Christian Holm Hansen 2021	72	11068		0.65 [ 0.51; 0.8
Guevara, R. 2022	44	9962		0.44 [ 0.32; 0.5
Carazo, S. 2022	22855	111239		20.55 [20.31; 20.7
Murugesan, M. 2022	32	1355		2.36 [ 1.62; 3.3
Evthorsson, E. 2022	1327	11536		11.50 [10.93; 12.1
	1	6014		
Ringlander, J. 2022				0.02 [0.00; 0.0
Jang, E. J. 2022		16130855		0.35 [0.34; 0.3
Dhumal, S. 2022	6	408		1.47 [ 0.54; 3.1
Rosenberg, M. 2022	74	12272		0.60 [0.47; 0.7
Alhaddad, Fatemah 2022	30	14320		0.21 [0.14; 0.3
Random effects model		16539330 0		0.71 [0.33; 1.5
Heterogeneity: $I^2 = 100\%$ , $\tau^2 = 2.9$	9817, p = 0	10333330		0.71 [0.00, 1.0
Group = >90				
Aparna Mukherjeel 2021	58	1300 🔤		4.46 [3.40; 5.7
Rennert, L. 2021	33	2010		1.64 [1.13; 2.3
Prete, C. A., Jr. 2022	33	174		18.97 [13.43; 25.5
Pilz, S. 2021	40	14840		0.27 [ 0.19; 0.3
	40			0.27 [0.19, 0.3
Random effects model Heterogeneity: $I^2 = 99\%$ , $\tau^2 = 2.59$	19. p < 0.01	18324 🥌		2.55 [ 0.53; 11.3
Group = 90				
Megan M. Sheehan BS 2021	62	386336		0.02 [0.01; 0.0
Anne Rivelli 2022	156	2625		5.94 [ 5.07; 6.9
Stephen Morris 2022	5	210 -		2.38 [ 0.78; 5.4
Godwin E. Akpan 2022	13	5459		0.24 [ 0.13; 0.4
		1572		
Lara J. Akinbami 2021	40			
Boopathy Nisha 2022	4	350		1.14 [0.31; 2.9
Nhu Ngoc Nguyen 2022	209	55338		0.38 [ 0.33; 0.4
Qureshi, A. I. 2021	63	9119		0.69 [ 0.53; 0.8
David J. Bean 2021	75	9910		0.76 [ 0.60; 0.9
Ferhat Arslan 2022	27	32607		0.08 [ 0.05; 0.1
Alexander Lawandi 2021	253	131773		0.19 [0.17; 0.2
Anna Jeffery-Smith1 2021	1	88 💻		1.14 [ 0.03; 6.1
Mark S Graham 2021	249	36509		0.68 [ 0.60; 0.7
Chiara Sacco 2022	249121	8413857		2.96 [2.95; 2.9
Etienne Racine 2022	6	569		1.05 [ 0.39; 2.2
Yusuf Arslan 2022	421	58811		0.72 [ 0.65; 0.7
Oriol Yuguero 2022	421	27758		0.05 [0.03; 0.0
				0.05 [0.03; 0.0
Sne zana Medi c 2022	13792	362650		3.80 [ 3.74; 3.8
Anna A Mensah 2022	2343	688418		0.34 [ 0.33; 0.3
Belloch García, S. L. 2022	40	15687		0.25 [ 0.18; 0.3
Hall, V. 2022	210	9488		2.21 [ 1.93; 2.5
Rothberg, M. B. 2022	1230	54233		2.27 [2.14; 2.4
Lacy, J. 2022	2815	258935		1.09 [1.05; 1.1
Spicer, K. B. 2022	593	41647		1.42 [ 1.31; 1.5
Flacco, M. E. 2022	24	7173		0.33 [0.21; 0.5
Levin-Rector, A. 2022	2583	349827		0.74 [0.71; 0.7
Arslan, Y. 2022	421	58811		0.72 [0.65; 0.7
Barzegar, M. 2022	22	2013		1.09 [ 0.69; 1.6
Managh A A 2022				1.05 [0.09, 1.0
Mensah, A. A. 2022	2343	688418		0.34 [0.33; 0.3
Cohen, C. 2022	87	749	*	11.62 [ 9.41; 14.1
Nguyen, N. N. 2022	209	55338		0.38 [0.33; 0.4
Al-Otaiby, M. 2022	4454	556750		0.80 [ 0.78; 0.8
Morris, C. P. 2022	122	755		16.16 [13.60; 18.9
	4106	600000		0.68 [ 0.66; 0.7
Marinov, G. K. 2022				
Ochoa-Hein, E. 2022	73	1388 🔲		5.26 [4.14; 6.5
Akpan, Godwin E. 2022	13	5459		0.24 [0.13; 0.4
Pecoraro, V. 2022	1258	35692		3.52 [ 3.34; 3.7
				5.94 [ 5.07; 6.9
	156			
Rivelli, Anne 2022 Random effects model	156	2625 III 12968947		0.87 [0.55; 1.3

Benjamin Davido 2021	5	236 📥	2.12 [0.69; 4.87]
Christian Holm Hansen 2021	72	11068 📖	0.65 [0.51; 0.82]
Laith J. Abu-Raddad1 2021	219	42915	0.51 [0.45; 0.58]
Laith J. Abu-Raddad2 2021	259	291309	0.09 [0.08; 0.10]
Nhu Ngoc Nguyen 2022	209	55338	0.38 [0.33; 0.43]
Mark S Graham 2021	249	36509	0.68 [0.60; 0.77]
Gazit, S1 2022	1374	107413	1.28 [1.21; 1.35]
Gallais, F 2021	1	393	0.25 [0.01; 1.41]
Anna Jeffery-Smith2 2021	23	656	3.51 [2.24; 5.21]
Marinov, G. K. 2022	4106	600000	0.68 [0.66; 0.71]
Common effect model		1145837	0.57 [0.56; 0.58]
Random effects model		8	0.64 [0.35; 1.18]
Heterogeneity: $I^2 = 99\%$ , $\tau^2 = 0.9204$	4, <i>p</i> = 0	2	
variant = Delta		1	
Sachin Dhumal 2022	6	408	1.47 [0.54; 3.17]
Victor Manuylov 2021	46	167	27.54 [20.93; 34.98]
Gazit, S2 2022	127	62250	0.20 [0.17; 0.24]
Mensah, A. A. 2022	2343	688418	0.34 [0.33; 0.35]
Cohen, C. 2022	87	749	11.62 [9.41; 14.13]
Al-Otaiby, M. 2022	4454	556750	0.80 [0.78; 0.82]
Common effect model		1308742	0.54 [0.53; 0.55]
Random effects model Heterogeneity: $I^2 = 100\%$ , $\tau^2 = 3.572$	22, $p = 0$		1.80 [0.40; 7.72]
variant = Gamma		2	
Prete, C. A., Jr. 2022	33	174	18.97 [13.43; 25.59]
	00		10.01 [10.10, 20.00]
variant = Omicron Guevara, R. 2022	44	9962	0.44 [0.32; 0.59]
Carazo, S. 2022	22855	111239	20.55 [20.31; 20.78]
Rothberg, M. B. 2022	1230	54233	2.27 [2.14; 2.40]
Eythorsson, E. 2022	1327	11536	11.50 [10.93; 12.10]
Jang, E. J. 2022		16130855	0.35 [0.34; 0.35]
Ochoa-Hein, E. 2022	73	1388	5.26 [4.14; 6.57]
Piazza, M. F. 2022	15715	335117	4.69 [4.62; 4.76]
Common effect model		16654330	0.58 [ 0.58; 0.59]
Random effects model			3.08 [1.02; 8.94]
Heterogeneity: $I^2 = 100\%$ , $\tau^2 = 2.249$	97. p = 0	333	and a second sec

	Exper	imental	Control					
Study	Events	Total	Events	Total	<b>Risk Ratio</b>	RR	95%-CI	Weight
Christian Holm Hansen 2021	72	11069	16819	514271		0.20	[0.16; 0.25]	10.1%
Megan M. Sheehan BS 2021	62	8783	5449	136031	50 C	0.18	[0.14; 0.23]	10.0%
Chemaitelly, H. 2021	263	44558	3148	41673	10	0.08	[0.07; 0.09]	10.4%
Laith J. Abu-Raddad1 2021	32	43044	3185	149923	-	0.03	[0.02; 0.05]	9.6%
Laith J. Abu-Raddad2 2021	44	42848	2679	132701	E23	0.05	[0.04; 0.07]	9.8%
Rennert, L. 2021	44	1977	1697	12383	122	0.16	[0.12: 0.22]	9.8%
Prete, C. A., Jr. 2022	8	123	51	115	-	0.15	[0.07; 0.30]	7.5%
Pilz, S. 2021	40	14800	253581	8632059		0.09	[0.07; 0.13]	9.7%
Anna Jeffery-Smith2 2021	10	646	165	556		0.05	[0.03; 0.10]	7.9%
Antonio Leidi 2022	5	743	830	8879		0.07	[0.03; 0.17]	6.4%
Anna Jeffery-Smith1 2021	1	87	18	55		0.04	[0.00; 0.26]	2.5%
Leidi, A	5	498	154	996		0.06	[0.03; 0.16]	6.4%
Random effects model		169176		9629642		0.09	[0.06; 0.13]	100.0%