Estimation of pertussis household transmission rates and the impact of cocooning vaccination strategies on infant pertussis

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Supplemental Digital Content

This file contains five supplemental online tables. eTables 1-2 contain the data presented in Figure 1 of the main text, eTable 3 gives a mathematical specification of the transmission matrices for the models considered, and eTables 4-5 present results of analyses assuming frequency-dependent transmission (eTable 4) or an exponentially distributed infectious period (eTable 5). Data are also available on request from the corresponding author.

eTable 1. Overview of the household outbreak data for households with an infant as index case. The first column (i) gives the household identifier, and the subsequent columns give the number of household infections ($j_1,\ldots,j_4$), the number of initially susceptible persons ($n_1,\ldots,n_4$), and the number of primary cases ($a_1,\ldots,a_4$).

i	j1	j2	j3	j4	n1	n2	n3	n4	a1	a2	a3	a4
1	1	1	0	0	1	1	1	0	0	0	0	1
2	0	0	0	0	0	1	1	2	1	0	0	0
3	0	0	0	0	0	1	1	2	1	0	0	0
4	1	0	0	0	1	0	1	0	0	1	0	0
5	0	0	0	0	0	1	1	3	1	0	0	0
6	1	0	0	0	1	0	1	3	0	1	0	1
7	0	1	0	0	0	1	0	3	1	0	0	0
8	1	0	0	0	1	0	0	2	0	1	0	0
9	1	1	0	0	1	1	0	0	0	0	1	0
10	0	1	0	2	0	1	1	2	1	0	0	0
11	0	0	1	0	0	1	1	0	1	0	0	0
12	0	0	1	0	0	0	1	0	1	1	0	0
13	1	0	0	0	1	1	1	0	0	0	0	1
14	1	0	0	0	1	1	1	0	0	0	0	1
15	0	0	0	0	0	1	1	1	1	0	0	0
16	0	0	0	0	0	0	1	0	1	1	0	0
17	0	0	0	0	0	1	1	1	1	0	0	0
18	0	0	0	0	0	1	1	1	1	0	0	0
19	1	0	0	1	1	0	1	1	0	1	0	0
20	1	1	0	1	1	1	0	1	0	0	1	0
21	0	0	0	0	0	1	1	1	1	0	0	0
22	0	0	0	0	0	1	1	1	1	0	0	0
23	0	0	0	0	0	1	0	3	1	0	0	0
24	0	0	0	0	0	1	1	0	1	0	0	0
25	0	1	1	0	0	1	1	0	1	0	0	0
26	1	0	1	0	1	1	1	0	0	0	0	1
27	0	0	0	0	0	1	1	0	1	0	0	0
28	1	0	0	0	1	1	1	2	0	0	0	1
29	0	1	0	0	0	1	1	0	1	0	0	0
30	1	0	1	0	1	0	1	0	0	1	0	0
31	0	1	0	0	0	1	1	0	1	0	0	0
32	1	0	0	0	1	1	1	0	0	0	0	1
33	1	1	0	0	1	1	1	0	0	0	0	1
34	0	0	0	0	0	1	1	1	1	0	0	0
35	1	0	0	0	1	0	0	0	0	1	1	1
36	1	0	0	0	1	0	1	0	0	1	0	1
37	1	1	0	0	1	1	1	0	0	0	0	1
38	1	0	1	0	1	1	1	0	0	0	0	1
39	0	0	1	0	0	0	1	2	1	1	0	1
40	1	0	0	0	1	0	1	0	0	1	0	0
41	0	1	0	0	0	1	1	0	1	0	0	0
42	1	0	0	0	1	0	1	2	0	1	0	0
43	1	0	0	0	1	0	0	1	0	1	1	0
44	1	0	0	2	1	0	0	3	0	1	1	0
45	1	0	0	0	1	0	1	0	0	1	0	0
46	1	1	0	1	1	1	1	1	0	0	0	2
47	1	1	0	0	1	1	1	1	0	0	0	1
48	1	0	1	3	1	0	1	3	0	1	0	0
49	0	0	1	1	0	1	1	1	1	0	0	0
50	1	1	0	1	1	1	0	1	0	0	1	0
51	1	0	1	0	1	0	1	0	0	1	0	0
52	0	1	0	0	0	1	1	0	1	0	0	0
53	0	1	0	0	0	1	1	0	1	0	0	0
54	1	1	0	1	1	1	1	2	0	0	0	1
55	0	0	0	0	0	1	1	2	1	0	0	0
56	1	0	0	1	1	0	1	3	0	1	0	0
57	1	0	0	0	1	0	1	3	0	1	0	0
58	1	0	0	1	1	0	1	1	0	1	0	0
59	1	1	0	0	1	1	0	0	0	0	1	2
60	0	0	0	0	0	1	1	2	1	0	0	0
61	0	1	0	0	0	1	1	0	1	0	0	1
62	1	0	0	0	1	0	1	0	0	1	0	0
63	1	0	0	0	1	1	0	2	0	0	0	1
64	1	1	1	1	1	1	1	1	0	0	0	1
65	0	0	0	1	0	1	1	3	1	0	0	0
66	0	0	1	0	0	1	1	2	1	0	0	0
67	0	0	0	0	0	1	1	2	1	0	0	0
68	1	1	0	0	1	1	1	0	0	0	0	1
69	0	0	0	0	0	0	0	2	1	1	0	0
70	0	0	0	0	0	1	1	0	1	0	0	0
71	1	1	0	0	1	1	1	0	0	0	0	1
72	1	0	1	0	1	0	1	0	0	1	0	0
73	0	0	0	0	0	1	1	0	1	0	0	1
74	0	1	0	1	0	1	1	2	1	0	0	0
75	1	0	1	0	1	0	1	0	0	1	0	0
76	1	1	0	0	1	1	1	0	0	0	0	1
77	1	1	0	1	1	1	1	1	0	0	0	1
78	1	0	1	1	1	0	1	1	0	1	0	0
79	0	0	0	0	0	1	1	1	1	0	0	0
80	0	0	0	1	0	0	1	3	1	1	0	0
81	0	0	0	0	0	1	1	1	1	0	0	0
82	0	0	0	1	0	1	1	2	1	0	0	0
83	1	0	0	0	1	1	1	0	0	0	0	1
84	0	1	0	0	0	1	0	0	1	0	0	0
85	1	1	0	0	1	1	0	0	0	0	1	0
86	1	1	0	0	1	1	0	1	0	0	1	0
87	1	0	0	1	1	1	1	2	0	0	0	1
88	1	0	0	2	1	0	1	4	0	1	0	0
89	0	1	0	0	0	1	1	0	1	0	0	0
90	1	0	0	0	1	0	0	0	0	0	1	1
91	1	0	0	4	1	1	1	4	0	0	0	1
92	1	0	0	0	1	0	1	0	0	1	0	1
93	1	1	1	1	1	1	1	3	0	0	0	1
94	0	0	0	1	0	1	1	3	1	0	0	0
95	1	0	0	0	1	1	0	2	0	0	1	0
96	1	0	0	0	1	0	1	0	0	1	0	0
97	1	1	0	0	1	1	0	1	0	0	1	0
98	0	0	0	0	0	1	1	1	1	0	0	0
99	1	0	0	2	1	0	1	2	0	1	0	0
100	1	1	0	0	1	1	0	0	0	0	1	0
101	1	1	0	0	1	1	0	0	0	0	1	0
102	0	1	0	0	0	1	1	1	1	0	0	2
103	1	0	0	0	1	0	1	0	0	1	0	0
104	0	0	0	0	0	1	1	3	1	0	0	0
105	1	0	0	1	1	1	0	1	0	0	1	0
106	1	1	0	0	1	1	0	0	0	0	1	0
107	0	0	0	0	0	1	0	0	1	0	0	0
108	1	0	0	0	1	0	1	0	0	1	0	0
109	1	1	1	0	1	1	1	0	0	0	0	1
110	1	0	0	1	1	1	1	2	0	0	0	1
111	0	0	0	0	0	1	1	0	1	0	0	0
112	0	0	0	0	0	1	1	0	1	0	0	0
113	1	0	0	0	1	1	1	1	0	0	0	1
114	1	1	0	0	1	1	0	3	0	0	1	0
115	1	0	0	0	1	0	1	0	0	1	0	0
116	1	0	1	0	1	1	1	1	0	0	0	1
117	1	0	1	1	1	0	1	1	0	1	0	0
118	0	0	0	0	0	1	1	1	1	0	0	0
119	1	0	0	0	1	1	0	0	0	0	1	0
120	0	0	1	1	0	1	1	1	1	0	0	0
121	1	0	0	0	1	0	1	0	0	1	0	0
122	1	0	0	1	1	0	1	1	0	1	0	0
123	0	0	1	0	0	1	1	0	1	0	0	0
124	0	0	0	2	0	1	1	3	1	0	0	0
125	1	1	0	0	1	1	0	2	0	0	1	0
126	1	0	0	1	1	0	1	1	0	1	0	1
127	0	1	0	1	0	1	1	1	1	0	0	0
128	0	1	1	0	0	1	1	1	1	0	0	0

eTable 2. Overview of the household outbreak data for the households with a non-infant as index case. In all cases the index case was also a primary case. The first column (i) gives the household identifier, and the subsequent columns give the number of household infections ($j_1,\ldots,j_4$), the number of initially susceptible persons ($n_1,\ldots,n_4$), and the number of primary cases ($a_1,\ldots,a_4$).

i	j1	j2	j3	j4	n1	n2	n3	n4	a1	a2	a3	a4
1	0	0	0	0	1	0	1	1	0	1	0	0
2	0	0	0	0	1	1	1	1	0	0	0	1
3	1	0	0	1	1	0	0	1	0	1	1	0
4	0	0	0	2	1	1	1	2	0	0	0	1
5	0	0	0	0	1	1	1	1	0	0	0	1
6	1	1	0	0	1	1	1	0	0	0	0	1
7	0	0	0	1	1	1	0	1	0	0	1	0
8	0	0	0	0	1	1	1	1	0	0	0	1
9	0	0	0	0	1	1	1	1	0	0	0	1
10	0	0	0	0	1	1	0	0	0	0	1	0
11	0	0	0	0	1	1	1	0	0	0	0	1
12	0	0	0	0	1	1	1	1	0	0	0	1

eTable 3. Overview of the transmission matrices specifying the transmission rates between infants, mothers, fathers, and siblings for the different model scenarios. Units of the transmission rates are per infectious period. In the frequency-dependent transmission model with fixed infectious periods the transmission probability between two persons, assuming that the receiver is initially susceptible and not infected by another person, is given by $1-\exp\left(-\beta_{ij}/N\right)$, where N represents household size and β_{ij} the transmission rate between a sender of type *j* and receiver of type *i*.

model	description	transmission matrix (rates per infectious period)
A	no structure	$\beta\begin{pmatrix}1&1&1&1\\1&1&1&1\\1&1&1&1\\1&1&1&1\end{pmatrix}$
B	variable infectiousness	$\beta\begin{pmatrix}1&f_M&f_F&f_O\\1&f_M&f_F&f_O\\1&f_M&f_F&f_O\\1&f_M&f_F&f_O\end{pmatrix}$
C	variable susceptibility	$\beta\begin{pmatrix}1&1&1&1\\g_M&g_M&g_M&g_M\\g_F&g_F&g_F&g_F\\g_O&g_O&g_O&g_O\end{pmatrix}$
D	variable infectiousness and susceptibility (proportionate mixing)	$\beta\begin{pmatrix}1&f_M&f_F&f_O\\g_M&g_Mf_M&g_Mf_F&g_Mf_O\\g_F&g_Ff_M&g_Ff_F&g_Ff_O\\g_O&g_Of_M&g_Of_F&g_Of_O\end{pmatrix}$
C(1)	variable susceptibility of fathers	$\beta\begin{pmatrix}1&1&1&1\\1&1&1&1\\g_F&g_F&g_F&g_F\\1&1&1&1\end{pmatrix}$
C(2)	variable susceptibility of fathers and specific transmission rates to infants	$\beta\begin{pmatrix}1&h_M&h_F&h_O\\1&1&1&1\\g_F&g_F&g_F&g_F\\1&1&1&1\end{pmatrix}$
C(3)	variable susceptibility of fathers and a specific transmission rate from mother to infant	$\beta\begin{pmatrix}1&h_M&1&1\\1&1&1&1\\g_F&g_F&g_F&g_F\\1&1&1&1\end{pmatrix}$

eTable 4. Overview of the statistical analyses assuming frequency-dependent transmission and an exponentially distributed infectious period. The model odds are relative to model C(3) in the main text.

model	parameter estimate	(95%CI)	number of parameters	AIC	model odds
A	$\hat{\beta} = 0.670$	$(0.53 - 0.84)$	1	400.86	<0.001
B	$\hat{\beta} = 1.09$	$(0.67 - 1.7)$	4	401.02	<0.001
	$\hat{f}_M = 0.162$	$(0 - 0.88)$			
	$\hat{f}_F = 0.704$	$(0.14 - 2.1)$			
	$\hat{f}_O = 0.482$	$(0.18 - 1.1)$			
C	$\hat{\beta} = 0.712$	$(0.11 - 2.4)$	4	385.20	0.062
	$\hat{g}_M = 1.53$	$(0.44 - 9.1)$			
	$\hat{g}_F = 0.461$	$(0.18 - 2.8)$			
	$\hat{g}_O = 1.16$	$(0.47 - 6.9)$			
D	$\hat{\beta} = 1.27$	$(0.58 - 3.6)$	7	387.53	0.019
	$\hat{f}_M = 0.486$	$(0 - 1.8)$			
	$\hat{f}_F = 0.496$	$(0.10 - 1.7)$			
	$\hat{f}_O = 0.412$	$(0.17 - 1.0)$			
	$\hat{g}_M = 1.30$	$(0.16 - 3.8)$			
	$\hat{g}_F = 0.401$	$(0.20 - 1.23)$			
	$\hat{g}_O = 1.04$	$(0.30 - 3.8)$			
C(1)	$\hat{\beta} = 0.939$	$(0.72 - 1.2)$	2	382.84	0.20
	$\hat{g}_F = 0.356$	$(0.21 - 0.57)$			
C(2)	$\hat{\beta} = 0.860$	$(0.64 - 1.2)$	5	385.33	0.058
	$\hat{g}_F = 0.424$	$(0.25 - 0.70)$			
	$\hat{h}_M = 3.39$	$(0.54 - 47)$			
	$\hat{h}_F = 0.262$	$(0.041 - 2.1)$			
	$\hat{h}_O = 0.756$	$(0.12 - 2.5)$			
C(3)	$\hat{\beta} = 0.915$	$(0.69 - 1.2)$	3	383.07	0.18
	$\hat{g}_F = 0.400$	$(0.23 - 0.66)$			
	$\hat{h}_M = 4.63$	$(0.49 - 59)$			

eTable 5. Statistical analyses assuming density-dependent transmission and an infectious period of fixed duration. NA: Confidence bounds could not reliably be calculated due to numerical instabilities.

model	parameter estimate	(95%CI)	number of parameters	AIC	model odds
A	$\hat{\beta} = 0.155$	$(0.13 - 0.19)$	1	404.69	<0.001
B	$\hat{\beta} = 0.143$	$(0.11 - 0.18)$	4	395.57	<0.001
	$\hat{f}_M = 4.04$	$(0.51 - > 10)$			
	$\hat{f}_F = 0.141$	$(0.015 - 0.85)$			
	$\hat{f}_O = 0.723$	$(0.13 - 0.19)$			
C	$\hat{\beta} = 0.135$	$(0.029 - 0.41)$	4	395.17	<0.001
	$\hat{g}_M = 1.92$	$(0.34 - 3.3)$			
	$\hat{g}_F = 0.636$	$(0.22 - 3.8)$			
	$\hat{g}_O = 1.18$	$(0.37 - 6.3)$			
D	$\hat{\beta} = 1.27$	NA	7	395.42	<0.001
	$\hat{f}_M = 0.486$	NA			
	$\hat{f}_F = 0.496$	NA			
	$\hat{f}_O = 0.412$	NA			
	$\hat{g}_M = 1.30$	NA			
	$\hat{g}_F = 0.401$	NA			
	$\hat{g}_O = 1.04$	NA			
C(1)	$\hat{\beta} = 0.195$	$(0.15 - 0.24)$	2	394.07	<0.001
	$\hat{g}_F = 0.446$	$(0.27 - 0.70)$			
C(2)	$\hat{\beta} = 0.173$	NA	5	391.74	0.002
	$\hat{g}_F = 0.560$	NA			
	$\hat{h}_M = 3.36$	NA			
	$\hat{h}_F = 0.178$	NA			
	$\hat{h}_O = 0.693$	NA			
C(3)	$\hat{\beta} = 0.180$	$(0.14 - 0.23)$	3	391.12	0.003
	$\hat{g}_F = 0.523$	$(0.31 - 0.84)$			
	$\hat{h}_M = 6.23$	$(1.4 - 21)$			