# Social contacts during the early phase of the SARS-Cov-2 epidemic in Finland

Kari Auranen
THL Corona Modeling Group/Finnish Institute for Health and Welfare

University of Turku

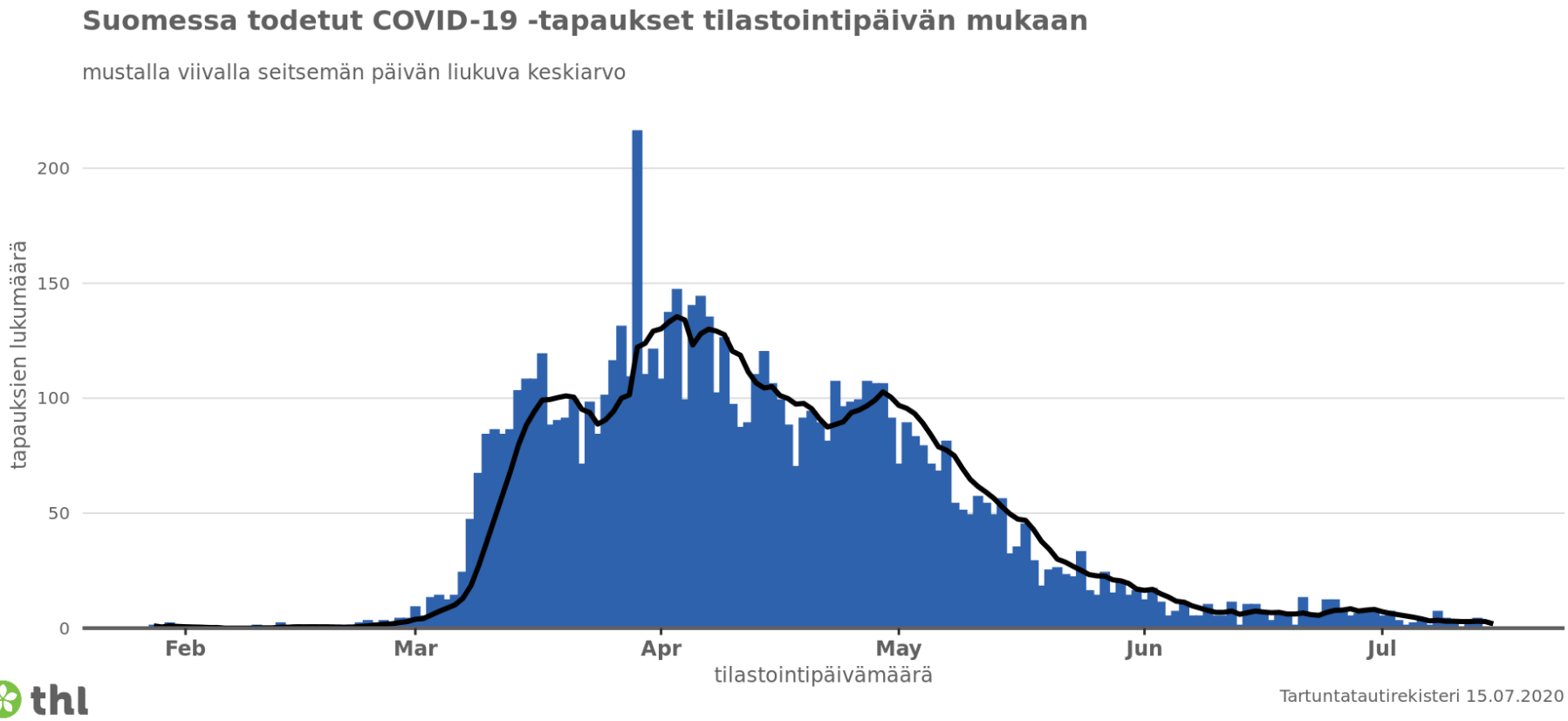

# SARS-CoV-2 epidemic in Finland

- Finland, a Northern European country, pop. 5,500,000
- The epidemic started in early March, 2020, with a number parallel introductions identified in travellers from Southern and Central Europe
- The first COVID19-related death occurred on March 20, when the epidemic was already in an exponentially increasing phase
- On March 16, the government imposed heavy legal measures and recommendations to endorse social distancing
  - Schools closed (up to mid May); face-to-face teaching stopped at the universities; gatherings of more than 10 people banned; endorsement for remote working; travel restrictions; publicity for social distancing and hand hygiene
  - Nevertheless, most shops have remained open and it had not been obligatory to wear masks
- Gradual opening of the society since early June, e.g. restaurants have been re-opened and many travel restrictions have been partially lifted

# SARS-CoV-2 epidemic in Finland (2)

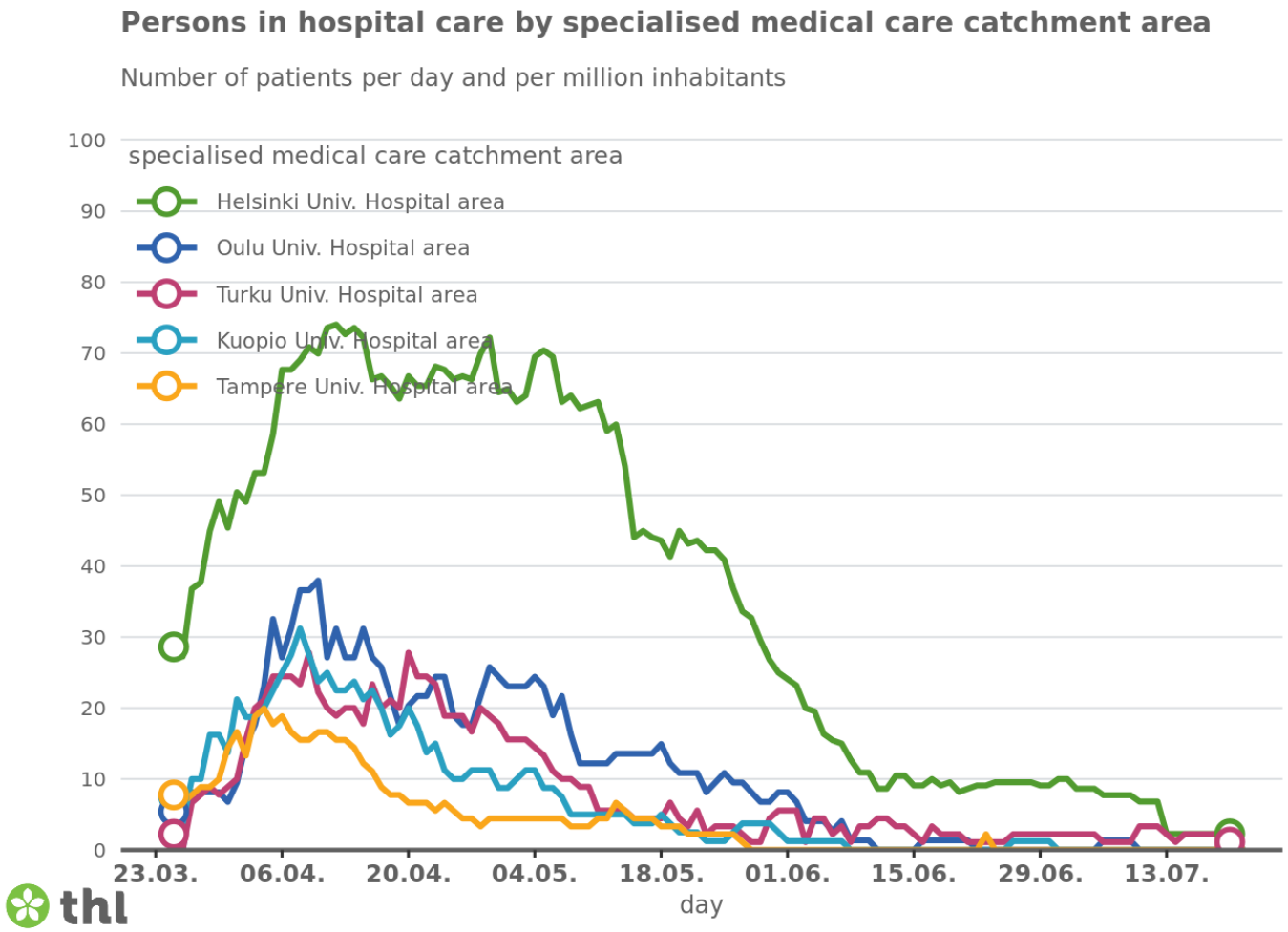
- The epidemic started declining in early April, i.e. 2–3 weeks after the onset of social distancing
- As of July 20, the cumulative incidence of COVID19-related deaths is 5.9 per 100,000
  - The corresponding numbers in Sweden and the U.S. are 55.6 and 43.3
- There has been c. 7300 detected cases (0.13% of the population)
- The peak daily incidence of detected cases (c. 150) was in early April
- More than 80% of hospitalisations and deaths in Finland have occurred in the extended capital region with a population of one fifth of the total population size

# SARS-CoV-2 cases in Finland




Ref: www.thl.fi

# Hospitalized cases (occupancy) by hospital district




Ref: www.thl.fi

# Social contacts and the transmission potential

- The basic reproduction number in the standard SEIR model with homogeneous mixing is $R_0 = pcd$, where
  - c is the rate of person-to-person contacts
  - p is the probability of infection at a contact of two individuals, one infectious and the other one susceptible
  - $d$ is the mean duration of infectiousness

- Generalizing to age-dependent contact rates, the basic reproduction number is the largest eigenvalue of the next generation matrix $pCd = p(c_{jk})d$
  - Here $c_{jk}$ is the number of contacts (per time unit) an individual of age class $k$ makes with individuals of age class $j$

Wallinga et al. 2006

# Reduction in the transmission potential?

- To use rates $c_{jk}$ in an epidemic model, the scaling factor $p$ needs to be estimated based on epidemiological data
- However, as long as $p$ and $d$ can be assumed to be constants, the reduction in the reproduction number depends only on the reduction in the rate of contacts
- The ratio of the reproduction numbers after vs. before social distancing are

$$\frac{\text{new R}}{R_0} = \frac{\text{largest eigenvalue of the new contact matrix } C_{new}}{\text{largest eigenvalue of the original contact matrix } C}$$

# POLYMOD survey

- In 2005, the POLYMOD survey revealed a clearly assortative pattern on social contacts in all participating countries (Mossong et al. 2008)
- In Finland, the contact matrices (transformed to the 2019 age distributions) for all contacts and physical ("skin-to-skin") contacts are as follows (participants = columns; contactees = rows)

2005, all contacts

C)

| | 0-9 | 10-19 | 20-29 | 30-39 | 40-49 | 50-59 | 60-69 | 70+ |
|---|---|---|---|---|---|---|---|---|
| 0-9 | 4.69 | 1.13 | 0.71 | 1.55 | 0.97 | 0.52 | 0.51 | 0.19 |
| 10-19 | 1.27 | 8.0 | 1.0 | 1.07 | 1.64 | 0.61 | 0.24 | 0.21 |
| 20-29 | 0.82 | 1.02 | 3.93 | 1.88 | 1.33 | 1.17 | 0.52 | 0.24 |
| 30-39 | 1.76 | 1.09 | 1.86 | 3.27 | 1.96 | 1.6 | 0.93 | 0.34 |
| 40-49 | 1.27 | 1.91 | 1.51 | 2.25 | 3.21 | 2.11 | 0.79 | 0.52 |
| 50-59 | 0.72 | 0.76 | 1.42 | 1.97 | 2.26 | 2.95 | 1.19 | 0.57 |
| 60-69 | 0.48 | 0.2 | 0.42 | 0.77 | 0.57 | 0.8 | 1.59 | 0.8 |
| 70+ | 0.19 | 0.2 | 0.21 | 0.31 | 0.41 | 0.42 | 0.89 | 2.21 |

2005, physical contacts

D)

| | 0-9 | 10-19 | 20-29 | 30-39 | 40-49 | 50-59 | 60-69 | 70+ |
|---|---|---|---|---|---|---|---|---|
| 0-9 | 2.69 | 0.7 | 0.43 | 1.02 | 0.57 | 0.24 | 0.4 | 0.1 |
| 10-19 | 0.79 | 3.33 | 0.32 | 0.43 | 0.78 | 0.19 | 0.11 | 0.1 |
| 20-29 | 0.5 | 0.33 | 1.53 | 0.38 | 0.2 | 0.26 | 0.11 | 0.04 |
| 30-39 | 1.16 | 0.43 | 0.38 | 1.03 | 0.39 | 0.28 | 0.21 | 0.1 |
| 40-49 | 0.75 | 0.91 | 0.23 | 0.45 | 0.99 | 0.46 | 0.25 | 0.2 |
| 50-59 | 0.34 | 0.23 | 0.32 | 0.34 | 0.49 | 0.82 | 0.39 | 0.2 |
| 60-69 | 0.37 | 0.09 | 0.09 | 0.17 | 0.18 | 0.26 | 0.79 | 0.36 |
| 70+ | 0.1 | 0.09 | 0.04 | 0.1 | 0.16 | 0.15 | 0.39 | 1.66 |

# Contacts during social distancing

- A new survey was conducted in Finland in April 2020, one month after the onset of social distancing

2020, all contacts

A)

| | 0-9 | 10-19 | 20-29 | 30-39 | 40-49 | 50-59 | 60-69 | 70+ |
|---|---|---|---|---|---|---|---|---|
| 0-9 | 1.3 | 0.28 | 0.19 | 0.85 | 0.43 | 0.12 | 0.11 | 0.06 |
| 10-19 | 0.31 | 1.39 | 0.19 | 0.14 | 0.8 | 0.37 | 0.04 | 0.03 |
| 20-29 | 0.23 | 0.21 | 0.83 | 0.25 | 0.26 | 0.39 | 0.17 | 0.05 |
| 30-39 | 1.07 | 0.16 | 0.26 | 0.89 | 0.36 | 0.3 | 0.24 | 0.1 |
| 40-49 | 0.51 | 0.87 | 0.25 | 0.33 | 0.72 | 0.44 | 0.22 | 0.13 |
| 50-59 | 0.16 | 0.44 | 0.42 | 0.31 | 0.49 | 0.79 | 0.25 | 0.13 |
| 60-69 | 0.14 | 0.05 | 0.18 | 0.24 | 0.24 | 0.25 | 0.59 | 0.23 |
| 70+ | 0.09 | 0.04 | 0.06 | 0.12 | 0.17 | 0.16 | 0.28 | 0.55 |

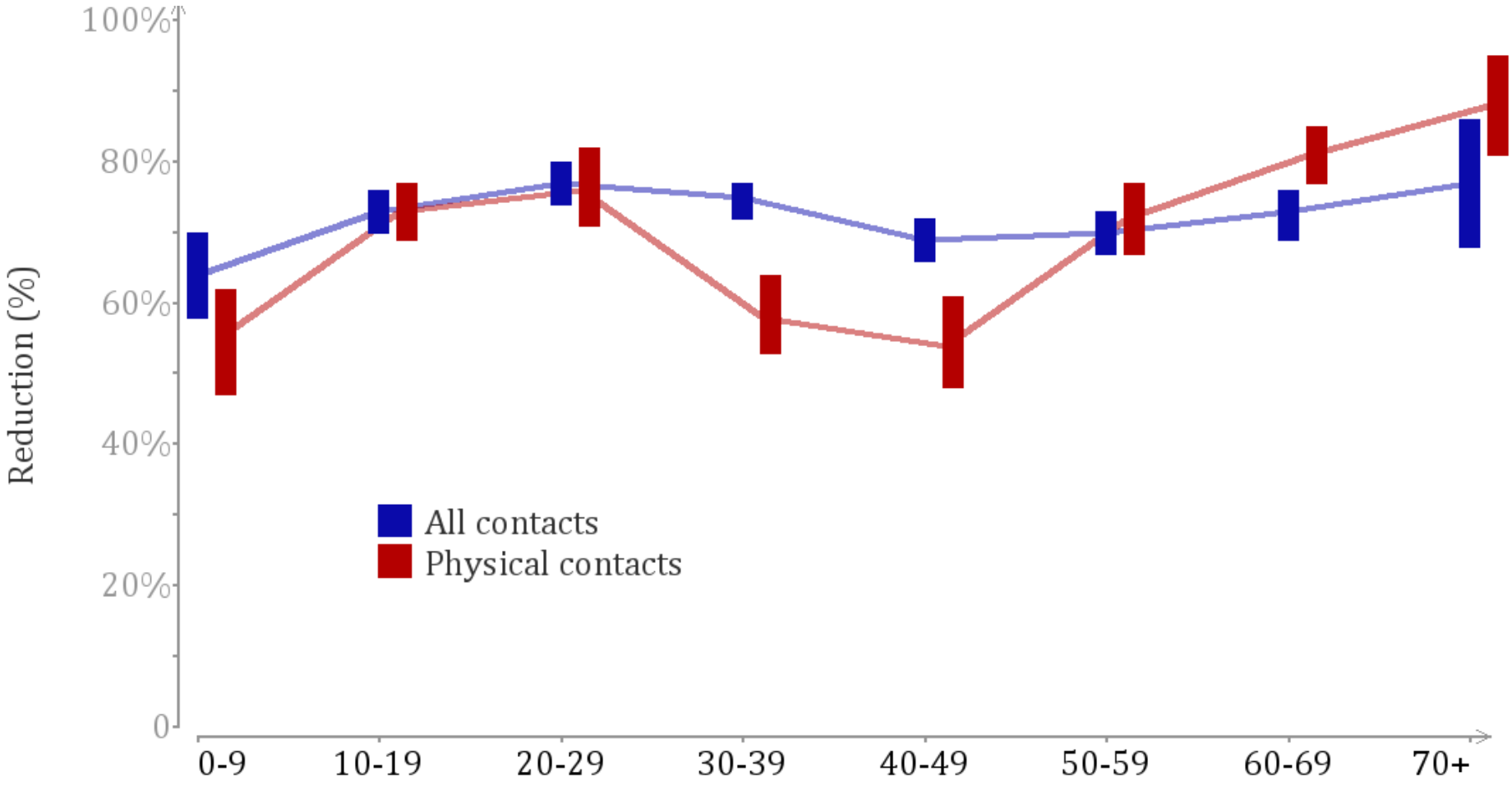
2020, physical contacts

B)

| | 0-9 | 10-19 | 20-29 | 30-39 | 40-49 | 50-59 | 60-69 | 70+ |
|---|---|---|---|---|---|---|---|---|
| 0-9 | 0.94 | 0.15 | 0.12 | 0.75 | 0.37 | 0.06 | 0.07 | 0.03 |
| 10-19 | 0.17 | 0.49 | 0.06 | 0.08 | 0.48 | 0.11 | 0.01 | 0.0 |
| 20-29 | 0.15 | 0.07 | 0.33 | 0.09 | 0.03 | 0.07 | 0.01 | 0.01 |
| 30-39 | 0.94 | 0.09 | 0.09 | 0.45 | 0.12 | 0.03 | 0.02 | 0.01 |
| 40-49 | 0.44 | 0.53 | 0.03 | 0.11 | 0.37 | 0.11 | 0.03 | 0.03 |
| 50-59 | 0.08 | 0.14 | 0.08 | 0.03 | 0.12 | 0.23 | 0.07 | 0.01 |
| 60-69 | 0.09 | 0.01 | 0.01 | 0.02 | 0.03 | 0.07 | 0.25 | 0.05 |
| 70+ | 0.05 | 0.01 | 0.01 | 0.01 | 0.04 | 0.02 | 0.06 | 0.22 |

- The number of daily contacts: $9.7 \rightarrow 2.7$
- The number of daily physical contacts: $3.7 \rightarrow 1.1$

# Reductions in contacts by age (Finland, April 2020)



# Reduction in the SARS-CoV-2 transmission potential

- Regarding physical contacts, thought to be the most important for transmission through droplet-spread
  - the overall reduction in their rate was 69% (95% CrI 66–73)
  - the reduction in the transmission potential was 59% (95% CrI 52–68), and if restricted to adults, 77% (95% CrI 70–89)
- The reductions were similar or slightly higher for all contacts
- The large reduction in contacts in the early part of the SARSCoV- 2 epidemic in Finland is likely to be a major contributor to the ready decline of the epidemic in the country since early April
- In particular, the reductions in the reproduction number were enought to take $R_0$'s in the range 2.4–4.0 down to or below one

# Estimation of contact matrices

- A negative binomial distribution was assumed for each observed count $c_{ijk}^{obs}$ ($i$ indexes the 1320 survey participants)
- Symmetry in population-level numbers of contacts was enforced through parameterization: $c_{jk} N_k = c_{kj} N_j$
- For each pair $(j, k)$ of two age classes, the log-likelihood of the mean and overdispersion parameters is

$$\log L_{jk}(c_{jk}, \theta_{jk}, \theta_{kj}; data) \quad =$$

$$\sum_{i=1}^{n_k} \log \text{Negbin}(c_{ijk}^{obs}; c_{jk}, \theta_{jk}) + \mathbf{1}_{j \neq k} \times [\sum_{i'=1}^{n_j} \log \text{Negbin}(c_{i'kj}^{obs}; c_{jk} N_k / N_j, \theta_{kj})$$

- For 8 age classes, 36 mean and 64 overdispersion parameters were estimated
- The posterior distribution of the model parameters is proportional to

$$\prod_{j \leq k} L_{jk}(c_{jk}, \theta_{jk}, \theta_{kj}; data) \prod_{j \leq k} p(c_{jk}) \prod_{j,k} p(\theta_{jk})$$

- Metropolis-Hastings algorithm was used to draw samples from the posterior distribution

# What about dynamic models?

- We have also built dynamic models to predict the likely course of the epidemic, both for long-term and short-term predictions
- These models were used to inform the government about the likely scenarios at the early phase of the first wave
- Currently, models are used to provide short-term predictions for the Ministry of Social Affairs and Health
- https://gitlab.com/2pi360/covid_model_finland_public

# References


- Auranen K, Shubin M, Karhunen M, Leino T, Nurhonen M. Social distancing during early epidemic had a large impact on the SARS-CoV-2 transmission potential in Finland. A submitted manuscript.
- https://thl.fi/en/web/infectious-diseases-and-vaccinations/what-s-new/coronavirus-covid-19-latest-updates/situation-update-on-coronavirus
- Mossong J, Hens N, Jit M, Beutels PH, Auranen K, Mikolajczyk R, et al. Social contacts and mixing patterns relevant to the spread of infectious diseases. PLoS Med. 2008; 5(3):e74, doi:10.1371/journal.pmed.0050074.
- Wallinga J, Teunis P, Kretzschmar M. Using data on social contacts to estimate age-speci
c transmission parameters for respiratory-spread infectious agents. Am J Epidemiol 2006; 164(10):93644. doi:10.1093/kwj317.