Supplementary material

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### Supplement part 1: PRISMA checklist

| Section/topic       | # | Checklist item                                                                                           | Reported on page # |
|---------------------|---|-----------------------------------------------------------------------------------------------------------|--------------------|
| **TITLE**           |   |                                                                                                           |                    |
| Title               | 1 | Identify the report as a systematic review, meta-analysis, or both.                                        | 1                  |
| **ABSTRACT**        |   |                                                                                                           |                    |
| Structured summary  | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | 2                  |
| **INTRODUCTION**    |   |                                                                                                           |                    |
| Rationale           | 3 | Describe the rationale for the review in the context of what is already known.                             | 3                  |
| Objectives          | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | 3 and Supplement part 2 |
| **METHODS**         |   |                                                                                                           |                    |
| Protocol and registration | 5 | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number. | 3                  |
| Eligibility criteria| 6 | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale. | 3                  |
| Information sources | 7 | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | 3 and Supplement part 3 |
| Search              | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | Supplement part 3  |
| Study selection     | 9 | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | 3                  |
| Data collection process | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | 3-4                |
| Data items | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made. | 4 |
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | 4 |
| Summary measures | 13 | State the principal summary measures (e.g., risk ratio, difference in means). | 4 |
| Synthesis of results | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., $I^2$) for each meta-analysis. | 4 |

| Section/topic | # | Checklist item | Reported on page # |
|----------------|---|----------------|-------------------|
| Risk of bias across studies | 15 | Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies). | 4 |
| Additional analyses | 16 | Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. | Not applicable |

**RESULTS**

| Study selection | 17 | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. | 4 and Figure 4-5, Table 1 and 2 |
| Study characteristics | 18 | For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations. | Supplement part 5 |
| Risk of bias within studies | 19 | Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12). | |
| Results of individual studies | 20 | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. | Table 1 and 2 |
| Synthesis of results | 21 | Present results of each meta-analysis done, including confidence intervals and measures of consistency. | Not applicable |
| Risk of bias across studies | 22 | Present results of any assessment of risk of bias across studies (see Item 15). | Not applicable |
| Additional analysis | 23 | Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]). | Not applicable |
### DISCUSSION

| Section                  | Page | Description                                                                                           | Reference |
|-------------------------|------|--------------------------------------------------------------------------------------------------------|-----------|
| Summary of evidence     | 24   | Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers). |           |
| Limitations             | 25   | Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias). |           |
| Conclusions             | 26   | Provide a general interpretation of the results in the context of other evidence, and implications for future research. |           |

### FUNDING

| Section | Page | Description                                                                                           | Reference |
|---------|------|--------------------------------------------------------------------------------------------------------|-----------|
| Funding | 27   | Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review. |           |

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097
Supplement part 2: PICO question

Participants/population: Male and female participants of all age groups

Intervention: Any vaccine against COVID-19 which has been approved for use in the European Union (or will be approved soon), including complete and incomplete dosing schedules

Comparators/control: placebo, no vaccination or a vaccine not directed against COVID-19 (active comparator), but also including head-to-head trials directly comparing different vaccines against COVID-19

Outcomes: 1. Efficacy and effectiveness-related outcomes: SARS-CoV2 infection (PCR-confirmed); hospitalisation due to COVID-19 (PCR-confirmed); ICU admission due to COVID-19 (PCR-confirmed); intubation and oxygen supply due to COVID-19 (PCR-confirmed); death due to COVID-19 (PCR-confirmed).
   2. Safety-related outcomes: local reactions; systemic events; severe adverse events; enhanced COVID-19 disease; adverse events of special interest (AESI), including solicited and unsolicited events
Supplement part 3: Search strategy

The following searches will be combined with the terms "vaccin*" and "immuniz*" and the brand names of the approved vaccines.

Search Syntax PubMed 1:
("Severe Acute Respiratory Syndrome Coronavirus 2" [Supplementary Concept] OR "COVID-19" [Supplementary Concept] OR "COVID 19 diagnostic testing" [Supplementary Concept] OR "COVID 19 drug treatment" [Supplementary Concept] OR "COVID 19 serotherapy" [Supplementary Concept] OR "COVID 19 vaccine" [Supplementary Concept] OR "Severe Acute Respiratory Syndrome Coronavirus 2"[tiab] OR ncov*[tiab] OR COVID*[tiab] OR sars-cov-2[tiab] OR "sars cov 2"[tiab] OR "SARS Coronavirus 2"[tiab] OR "Severe Acute Respiratory Syndrome CoV 2"[tiab] OR "Wuhan coronavirus"[tiab] OR "Wuhan seafood market pneumonia virus"[tiab] OR "SARS2"[tiab] OR "2019-nCoV"[tiab] OR "hcov-19"[tiab] OR "novel 2019 coronavirus"[tiab] OR "2019 novel coronavirus*"[tiab] OR "novel coronavirus 2019*"[tiab] OR "2019 novel human coronavirus*"[tiab] OR "human coronavirus 2019"[tiab] OR "coronavirus disease-19"[tiab] OR "corona virus disease-19"[tiab] OR "corona virus disease 2019"[tiab] OR "corona virus disease 2019"[tiab] OR "2019 coronavirus disease"[tiab] OR "2019 coronavirus disease 2019"[tiab] OR "novel coronavirus disease 2019"[tiab] OR "new coronavirus*"[tiab] OR "coronavirus outbreak"[tiab] OR "coronavirus epidemic"[tiab] OR "coronavirus pandemic"[tiab] OR "pandemic of coronavirus"[tiab]) AND ("2019/12/01"[PDAT] : "2099/12/31"[PDAT])

Search Syntax PubMed 2:
("wuhan"[tiab] or china[tiab] or hubei[tiab]) AND ("Severe Acute Respiratory Syndrome Coronavirus 2"[Supplementary Concept] OR "COVID-19" [Supplementary Concept] OR "COVID 19 diagnostic testing"[Supplementary Concept] OR "COVID 19 drug treatment"[Supplementary Concept] OR "COVID 19 serotherapy"[Supplementary Concept] OR "COVID 19 vaccine"[Supplementary Concept] OR "coronavirus*"[tiab] OR "corona virus*"[tiab] OR ncov*[tiab] OR COVID*[tiab] OR sars*[tiab])

Search Syntax Embase 1:
(‘severe acute respiratory syndrome coronavirus 2’[ti,ab OR 'severe acute respiratory syndrome coronavirus 2'/exp OR 'COVID 19'/exp OR ncov*:ti,ab OR COVID*:ti,ab OR 'sars cov 2':ti,ab OR 'sars-cov-2':ti,ab OR 'sars coronavirus 2':ti,ab OR 'sars coronavirus 2'/exp OR 'severe acute respiratory syndrome cov 2':ti,ab OR 'wuhan coronavirus':ti,ab OR 'wuhan seafood market pneumonia virus':ti,ab OR 'sars cov 2':ti,ab OR '2019-nCoV':ti,ab OR 'hcov-19':ti,ab OR 'novel 2019 coronavirus':ti,ab OR '2019 novel coronavirus*':ti,ab OR 'novel coronavirus 2019*':ti,ab OR 'coronavirus disease-19':ti,ab OR 'corona virus disease-19':ti,ab OR 'corona virus disease 19':ti,ab OR 'coronavirus disease 19':ti,ab OR '2019 coronavirus disease':ti,ab OR '2019 coronavirus disease 2019':ti,ab OR 'novel coronavirus disease 2019':ti,ab OR 'new coronavirus*':ti,ab OR 'coronavirus outbreak':ti,ab OR 'coronavirus epidemic':ti,ab OR 'coronavirus pandemic':ti,ab OR 'pandemic of coronavirus':ti,ab OR 'severe acute respiratory syndrome coronavirus 2 vaccine'/exp OR 'COVID 19 vaccine'/exp) AND 2020:py

Search Syntax Embase 2:
(‘wuhan’:ti,ab OR china:ti,ab OR hubei:ti,ab) AND (‘severe acute respiratory syndrome coronavirus 2’:ti,ab OR ‘severe acute respiratory syndrome coronavirus 2’/exp OR ‘severe acute respiratory
syndrome coronavirus 2' OR 'COVID*':ti,ab OR 'COVID 19'/exp OR 'COVID 19' OR coronavirus*:ti,ab OR 'corona virus*':ti,ab OR ncov:ti,ab OR COVID*:ti,ab OR sars*:ti,ab OR 'sars coronavirus 2'/exp)

Manual search in ArRvix, BioRxiv, ChemRxiv, MedRxiv, Preprints.org, ResearchSquare und SSRN
Supplement part 4: Outcome definitions in the included studies on efficacy and effectiveness of COVID-19 vaccines against SARS-CoV-2 infection (symptomatic and asymptomatic)

| Study (reference) | Outcome definition |
|-------------------|--------------------|
| Abu-Raddad (27)   | any documented infection (persons found positive by polymerasechain-reaction (PCR) testing for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)) |
| Amit (7)          | positive SARS-CoV-2 PCR |
| Andrejko (8)      | positive molecular test result for SARS-CoV-2 infection |
| Björk (28)        | first positive SARS-CoV2 test result |
| Britton (9)       | any positive PCR- or antigen-based SARS-CoV-2 test result |
| Chodick (10)      | at least one record of primary positive SARS-CoV-2 PCR test |
| Corchado-Garcia (29) | positive SARS-CoV-2 test |
| Dagan (11)        | documented SARS-CoV-2 infection confirmed by positive PCR test |
| EMA- Assessment report COVID-19 Vaccine Janssen (26) | first occurrence of SARS-CoV-2 infection (serologically and/or molecularly confirmed) |
| Emary (12)        | any NAAT positive infection (consisting of primary symptomatic cases, non-primary symptomatic cases (those with other symptoms such as nausea or diarrhea), asymptomatic cases, and cases for which symptoms were unknown) |
| Fabiani (30)      | SARS-CoV-2 infection, based on a positive antigenic test confirmed by RT-PCR on the same day |
| Glampson (13)     | first positive swab for all individuals (lateral flow test results were excluded) |
| Guijarro (14)     | SARS-CoV-2 positive antigen or PCR from nasal swabs |
| Author                  | Description                                                                 |
|-------------------------|-----------------------------------------------------------------------------|
| Haas (15)               | all SARS-CoV-2 infections (symptomatic and asymptomatic)                    |
| Hall (16)               | PCR confirmed SARS-CoV-2 infection                                          |
| Lumley (17)             | any PCR-positive result (i.e. either symptomatic or asymptomatic)           |
| Mason (31)              | SARS-CoV-2 positive PCR test result                                         |
| Menni (32)              | SARS-CoV-2 test result                                                      |
| Monge (18)              | documented SARS-CoV-2 infection                                             |
| Moustsen-Helms (19)     | laboratory confirmed SARS-CoV-2 infection (RT-PCR)                          |
| Pawlowski (20)          | tested positive for SARS-CoV-2 by PCR                                       |
| Pritchard (33)          | first new positive infection episodes                                       |
| Shrotri (21)            | first positive PCR test, indicating SARS-CoV-2 infection                    |
| Swift (34)              | positive molecular assay for SARS-CoV-2                                    |
| Tang (35)               | Any positive test result                                                    |
| Thompson (22)           | PCR-confirmed infection                                                     |
**Supplement part 5: Risk of bias assessments**

Risk of bias in randomized controlled trials

| Study         | Bias arising from the randomization process | Bias due to deviations from the intended interventions | Bias due to missing outcome data | Bias in measurement of the outcome | Bias in selection of reported result | Summary       |
|---------------|---------------------------------------------|------------------------------------------------------|---------------------------------|-----------------------------------|-------------------------------------|---------------|
| EMA Janssen   | low                                         | low                                                  | low                             | low                               | low                                 | low           |
| Emary         | low                                         | some concerns\(^1\)                                  | low                             | low                               | some concerns                       |               |

\(^1\) some participants received different dosages of the vaccine (low dose)

Risk of bias in non-randomized studies

| Study         | Bias due to confounding | Bias in selection of participants into the study/analysis | Bias in classification of interventions | Bias due to deviations from intended interventions | Bias due to missing data | Bias in measurement of outcomes | Bias in selection of reported result | Summary     |
|---------------|------------------------|----------------------------------------------------------|----------------------------------------|---------------------------------------------------|------------------------|-------------------------------|-------------------------------------|-------------|
| Abu-Raddad    | moderate\(^4\)         | low                                                      | low                                    | low                                               | low                    | low                           | low                   | moderate    |
| Amit          | serious\(^2\)          | low                                                      | low                                    | low                                               | low                    | low                           | low                   | serious     |
| Andrejko      | moderate\(^1\)         | low                                                      | moderate\(^3\)                         | low                                               | low                    | low                           | low                   | moderate    |
| Angel         | moderate\(^4\)         | low                                                      | low                                    | low                                               | low                    | low                           | low                   | moderate    |
| Name          | Severity | Severity | Severity | Severity | Severity | Severity | Severity | Severity |
|---------------|----------|----------|----------|----------|----------|----------|----------|----------|
| Björk         | moderate | low      | low      | low      | low      | low      | low      | moderate |
| Britton       | critical | low      | low      | low      | low      | low      | low      | critical |
| Chodick       | moderate | low      | low      | low      | low      | low      | low      | moderate |
| Corchado-Garcia| moderate | low      | low      | low      | low      | low      | low      | moderate |
| Dagan         | moderate | low      | low      | low      | low      | low      | low      | moderate |
| Fabiani       | moderate | low      | low      | low      | low      | low      | low      | moderate |
| Glampson      | moderate | low      | low      | low      | low      | low      | low      | moderate |
| Guijarro      | NA       | NA       | NA       | NA       | NA       | NA       | NA       | unclear  |
| Haas          | moderate | low      | low      | low      | low      | low      | low      | moderate |
| Hall          | moderate | low      | low      | low      | low      | low      | low      | moderate |
| Jones         | critical | low      | low      | low      | low      | low      | low      | critical |
| Lumley        | moderate | low      | low      | low      | low      | moderate | low      | moderate |
| Mason         | moderate | low      | low      | low      | low      | moderate | low      | moderate |
| Menni         | moderate | moderate | moderate | low      | low      | moderate | low      | moderate |
| Monge         | moderate | low      | low      | low      | low      | moderate | low      | moderate |
| Moustsen-Helms| serious  | low      | low      | low      | low      | low      | low      | serious  |
| Pawlowski     | moderate | low      | low      | low      | low      | low      | low      | moderate |
| Name   | Risk   | Test  | Vaccination Status | Compliance | Outcome  | Bias | Confounding | Asessment |
|--------|--------|-------|--------------------|------------|----------|------|-------------|-----------|
| Pritchard | moderate | low   | moderate           | low        | low      | low  | low         | moderate   |
| Shrotri  | moderate | low   | low                | low        | low      | low  | low         | moderate   |
| Swift    | moderate | low   | low                | low        | low      | low  | low         | moderate   |
| Tande    | moderate | low   | low                | low        | low      | low  | moderate    | moderate   |
| Tang     | critical | low   | low                | low        | low      | low  | low         | critical   |
| Thompson | moderate | low   | moderate           | low        | low      | low  | low         | moderate   |
| Zacay    | critical | low   | low                | low        | low      | low  | low         | critical   |

1 test-negative design; 2 only adjusted for community exposure rates; 3 self-reported vaccination status; 4 adjusted estimates reported, but residual confounding possible; 5 no confounder-adjusted estimates reported; 6 Due to study design (cohort study with elements of an interrupted time series), ROBINS-I could not be applied. According to the EPOC tool for interrupted time series, three out of seven domains would be judged as high risk of bias and two domains as unclear risk of bias. Therefore, the study was assessed here at unclear risk of bias. 7 some participants underwent symptomatic testing, but extent unknown; 8 selection bias cannot be excluded since App users might be special population; 9 self-reported outcome; 10 partly self-reported vaccination status; 11 participants with two doses excluded and results not reported; 12 unclear whether symptomatic persons were always excluded.