UK Health Security Agency

Effectiveness of non-pharmaceutical interventions to reduce transmission of COVID-19 in the UK

A rapid mapping review

Contents

Main messages

The purpose of this rapid mapping review was to identify and categorise primary studies that reported on the effectiveness of non-pharmaceutical interventions (NPIs) implemented in community settings to reduce the transmission of coronavirus (COVID-19) in the UK. Streamlined systematic methods were used, including literature searches (using sources such as Medline, Embase and medRxiv) and use of systematic reviews as sources to identify relevant primary studies.

The review includes 151 studies (search date: 1 March 2023) which were mapped onto an interactive evidence gap map (available at Evidence gap map: effectiveness of non-pharmaceutical interventions to reduce transmission of COVID-19 in the UK) on which the studies are visually displayed by NPI and study design (some studies reported on more than one NPI).

The findings of this review show that most of the published research on the effectiveness of NPIs implemented in community settings in the UK was focused on measures to identify and isolate those who are infectious or may become infectious (80 studies identified, including 30 on asymptomatic testing, 27 on contact tracing and 21 on isolation of cases) and on measures to reduce the number of contacts (71 studies identified, including 36 on lockdown and 17 each on school closures and limitation of social contacts).

Only 19 of the 151 studies identified reported on effectiveness of measures to reduce infection risk at individual level, of which 14 reported on face coverings. This suggests that there is an evidence gap for other measures within this category such as hand and respiratory hygiene, ventilation and cleaning (noting that studies that reported on packages of NPIs or on performance of specific protocols or products before implementation as an intervention were excluded).

Two-thirds of the evidence identified was based on modelling studies (100 out of 151 studies). There was a lack of experimental studies (2 out of 151 studies) and individual-level observational studies (22 out of 151 studies). Apart from test and release strategies for which 2 randomised controlled trials (RCTs) were identified, the body of evidence available on effectiveness of NPIs in the UK provides weak evidence in terms of study design, as it is mainly based on modelling studies, ecological studies, mixed-methods studies and qualitative studies. This is a key learning point for future pandemic preparedness: there is a need to strengthen evaluation of interventions and build this into the design and implementation of public health interventions and government policies from the start of any future pandemic or other public health emergency.

The aim of this mapping review was to identify and categorise the evidence available. The next steps are to critically appraise and synthesise the evidence identified on the effectiveness of individual NPIs implemented in community settings to reduce the transmission of COVID-19 in the UK. There is also a need to review and assess the evidence on the economic impact of NPIs as well as their wider impact, including on mental health and health inequalities.

Background

Non-pharmaceutical interventions (NPIs) have long played a crucial role in the control of infectious disease. Broadly speaking, an NPI is any type of public health intervention that is not primarily based on medication. In the early months of the COVID-19 pandemic, before pharmaceutical interventions such as vaccines became available, they formed the mainstay of the public health response. Once treatment options for COVID-19 and effective vaccination became available, the contribution of NPIs to the UK response decreased, although this was a gradual process (1, 2).

The term NPIs encompass a wide variety of measures that can be grouped into (3):

- measures to reduce infection risk at individual level, including physical distancing, surface cleaning, face coverings, hand and respiratory hygiene, and ventilation
- measures to identify and isolate those who are infectious or may become infectious, such as testing and isolation (also known as quarantine)
- measures to reduce the number of contacts, including lockdown, settings closures and limitation of social contacts (such as the 'rule of 6')
- measures to protect the most vulnerable (shielding of the most clinically vulnerable)
- travel and border restrictions to prevent or slow the importation of cases

During the COVID-19 pandemic, decisions about which NPIs to implement and when were affected by several factors including wider social and economic issues. Along with testing and contact tracing systems, the UK implemented a range of other NPIs such as lockdowns, mandatory use of face coverings in public, closure of settings and limitation of social contacts (4). These had to be weighed against several important considerations, including evidence of their effectiveness, their cost-effectiveness and impact on the economy, any potential adverse health effects, as well as ethical considerations and health equity impact of NPIs which may have impacted some vulnerable groups differently (1, 5 to 11).

In contrast to pharmaceutical interventions such as treatments and vaccines, there is a lack of strong evidence on the effectiveness of NPIs to reduce COVID-19 transmission, and for many NPIs the scientific consensus shifted over the course of the pandemic (3). Whilst this can be partly explained by the evolution of the epidemiology throughout the pandemic, including changes in seroprevalence and variants, there are specific limitations to the evidence-base for NPIs effectiveness (3,12). One of the limitations is that the evidence for effectiveness of NPIs is mainly based on observational studies, in contrast to pharmaceutical interventions for which randomised controlled trials (RCTs) can be more easily implemented. The reliance on observational studies results in an evidence-base prone to bias and confounding (13) which, in most cases, would be graded as low or very low certainty in the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) framework and rule out causal inference (14). There are also wider issues related to how to define and assess the effectiveness of interventions in real-world settings (including consideration of different possible exposures and routes of transmission as well as behavioural factors) and how to measure it (impact on

transmission versus socioeconomic impact as well as wellbeing and mental health). There are also ethical considerations to take into account when implementing RCTs during a pandemic.

An additional challenge when aiming to assess the effectiveness of NPIs during the COVID-19 pandemic is that NPIs were implemented in 'packages' (that is, a combination of different NPIs). In addition, these 'packages' were implemented differently across different countries (including across the UK nations) both in terms of the type of NPIs, and how and when they were implemented. NPIs have complex combined effects which complicates further the interpretation of the evidence and the assessment of the effectiveness of individual NPIs (2, 3, 12). There are also differences between the theoretical maximum impact of an NPI ('efficacy') and that observed in practice ('effectiveness'). These differences could be due to how NPIs were implemented, how their benefits and use were communicated to the public, the potential lack of or imperfect adherence (such as, not wearing a face covering properly) but also to a lack of support for behavioural changes, especially for the more vulnerable populations (15).

Behavioural changes are also an important consideration when interpreting the evidence, and it is not always possible to distinguish the impact of NPI policies implemented by a government from wider behavioural changes due to the pandemic context (3, 15). This highlights the need to embed behavioural and social sciences when conducting studies to assess the effectiveness of NPIs.

A large number of reviews on the effectiveness of NPIs to reduce the transmission of COVID-19 (including individual NPIs, packages of NPIs, and comparisons of different NPIs) have been published as illustrated by our initial scoping searches (see methods). In addition to review-level evidence, it is worth referring to the evidence considered by the Scientific Advisory Group for Emergencies (SAGE) to support the UK government response to the COVID-19 pandemic (16), the Royal Society programme of work on effectiveness of NPIs launched in October 2022 (17) as well as the chapter on NPIs from the technical report for future UK Chief Medical Officers (CMOs) which has informed this background section (3).

Despite the high number of primary studies, reviews and opinion pieces published on this topic, there are still many uncertainties and unknowns about the effectiveness of NPIs and it remains critical to develop a robust evidence base to inform pandemic preparedness and future response. A first step is to better understand the type of evidence that was generated during the pandemic on the effectiveness of NPIs as implemented in the UK.

Purpose

The purpose of this work was to use streamlined systematic methods to conduct a mapping review (18) to identify and categorise primary studies that reported on the effectiveness of NPIs implemented in community settings to reduce the transmission of COVID-19 in the UK.

The review question as defined in the protocol was ‘what evidence exists of the effectiveness of the NPIs as implemented in the community in the UK to control the COVID-19 pandemic?’

The primary outcomes of interest were those related to effectiveness in reducing transmission of COVID-19. Behavioural outcomes (such as adherence or perceptions) and socioeconomic impacts (such as education or working days lost) were considered when directly linked to an assessment of NPIs as implemented in the UK. Adverse effects of NPIs, including impact on inequalities, were out of scope of this project.

Methods

Review process

A mapping review was conducted, following streamlined systematic methodologies to accelerate the review process (18, 19). Primary studies relating to the effectiveness of NPIs as implemented in community settings in the UK to reduce the transmission of COVID-19 were identified using 2 main methods:

- for primary studies published (or available as a preprint) up to 31 December 2020, relevant systematic reviews were used as sources
- for primary studies published (or available as a preprint) between 1 January 2021 and 28 February 2023, a literature search (search date: 1 March 2023) using sources including Medline, Embase and medRxiv was undertaken by an information scientist

The screening, coding and mapping was done using EPPI-Reviewer web version (20) and the associated Eppi-Mapper tool (21). Title and abstract screening of records identified through literature searching was completed in duplicate by 2 to 4 reviewers for 15% of the studies, and the remaining 85% were screened by one reviewer (see Annexe A for more details). Full-text screening and data extraction were conducted by one reviewer and checked by a second.

The studies included in relevant systematic reviews were screened on title and abstract by one reviewer. Full-text screening of the primary studies identified in the reviews was done by one reviewer and checked by a second.

The codes used for the mapping (categories of study design, NPI and outcomes) were extracted in EPPI-Reviewer during full-text screening by one reviewer (checked by a second reviewer when completing the data extraction).

Summary information for each study was then extracted and reported in tabular form in a Microsoft Word document by one reviewer and checked by a second (the information extracted represents what was reported by the study authors in the given manuscript, even when unclear or possibly inaccurate). Risk of bias assessment was not undertaken. Future work includes critical appraisal and evidence synthesis.

Eligibility criteria

The inclusion and exclusion criteria are provided in Annexe A (Table A.1), including the list of NPIs considered for inclusion. All NPIs implemented in the community in the UK were considered, but NPIs specific to healthcare settings such as use of gowns or cohorting of staff and residents in care homes were excluded. Studies that reported on a ‘package’ of measures, without assessing effectiveness of individual NPIs were excluded. Similarly, studies reporting on ‘NPI index’ or ‘stringency of NPI’ were excluded.

Studies that reported on the impact of not having the intervention (for instance re-opening of schools or large events) were considered for inclusion. Ventilation was considered as an NPI as in the UK there was guidance to encourage people to open windows for ventilation. However, use of air cleaners or ultraviolet (UV) filters for ventilators were excluded as they were not an NPI formally implemented in the UK. For the purpose of this exercise, 'contact tracing' was considered as an intervention, including through the use of the NHS COVID-19 app. However, implementation of contact tracing, for instance through local tracing partnership, was out of scope.

Studies reporting on the efficacy of a device rather than on the effectiveness of an intervention were excluded (for instance, studies reporting on efficacy of a specific face covering or on the sensitivity and specificity of an antigen test were excluded but would have been included if they reported on effectiveness of this device to reduce COVID-19 transmission in real-world settings).

The main outcomes of interest were outcomes related to COVID-19 spread in the community, which were categorised as COVID-19 transmission, COVID-19 cases, COVID-19 hospitalisation, or COVID-19 mortality. Whilst COVID-19 hospitalisation and deaths are related to COVID-19 severity rather than transmission, it was agreed by the review team to include them when used as a proxy for COVID-19 transmission (this was especially true at the start of the pandemic when the main data available was hospitalisation and deaths). Similarly, COVID-19 cases are often used as a proxy for transmission but it was agreed by the review team to separate them out. This was in order to make the distinction between studies reporting on number of cases and studies that reported, for instance, on the reproduction number ('R number' which is the average number of secondary infections produced by a single infected person). Outcomes related to infection rates, number of secondary cases infectivity or whether or not an outbreak had actually happened were also coded under COVID-19 transmission. Any measures related to COVID-19 cases, hospitalisation, and mortality were considered for inclusion (including self-reported) as long as they were reported in the context of assessing the effectiveness of the interventions. Details about outcomes reported by each study are provided in the data extraction tables (see supplementary material). To note that we are using 'COVID-19 cases' to refer to both symptomatic and asymptomatic cases (instead of making the distinction between 'COVID-19 cases' for patients with the disease and 'people with SARS-CoV-2-positive tests' for those without COVID-19 symptoms).

The 'behavioural outcomes' mainly refers to adherence, compliance, perceptions and attitudes related to the NPIs implemented in the UK. Studies reporting on behavioural outcomes were included only if they were directly linked to effectiveness of NPIs as recommended by government policies: generic surveys on adherence and attitude on NPIs, studies on behaviours related to the pandemic in general, and behavioural change studies such as Germ Defence (22) were excluded.

The outcome 'lost time (school or work)' is a measure of how the different NPIs implemented impacted school or work attendance; this outcome was initially called 'socio-economic outcomes' but was then re-named to avoid confusion, as economic studies and studies reporting on health inequalities were out of scope.

COVID-19 surveillance studies and studies reporting on factors associated with transmission were excluded, unless they specifically looked at the association between NPI use and COVID-19 outcomes.

This work was limited to evidence reporting on NPIs implemented in the UK. Studies conducted in the UK but reporting on NPIs not implemented in the UK were excluded (for instance, UK studies looking at effectiveness of antibody testing to control the COVID-19 pandemic were excluded). Ecological studies that reported on several countries, including the UK, but did not report effectiveness results specific to the UK dataset were excluded.

Full details on the methodology are provided in Annexe A, the search strategy in Annexe B and the scoping searches to identify the systematic reviews used as sources of primary evidence in Annexe C. A protocol was produced a priori and is available on request.

Evidence

Search results

The database searches returned 15,846 records which were imported into Endnote. After removal of duplicates, 11,752 records were screened on title and abstract. Of these, 607 full-text articles were assessed for eligibility and 138 were included in this review.

The primary studies included in 25 relevant reviews identified through scoping searches (see Annexe C) were screened for eligibility, of which 29 studies were screened on full text. Of these, 11 met the inclusion criteria.

An additional 5 unique primary studies identified through internal lists of publications with UK Health Security Agency (UKHSA) involvement (see Annexe A) were screened on full text. Of these, 2 met the inclusion criteria.

The reference lists from relevant rapid reviews conducted by the UKHSA COVID-19 rapid evidence service (23), including the reviews on effectiveness of face coverings, transmission in school settings, transmission in public transport, and transmission within food manufacturing and processing settings, as well as the references included in the chapter on NPIs from the CMO technical report (3) were also screened. No unique studies were identified from these additional sources.

In total, 151 studies were included in this review. A Preferred Reporting Items for Systematic reviews and Meta-Analyses PRISMA diagram is provided in Annexe A. Details of the included studies can be found in Tables S.1 to S.6 (supplementary material or visit UKHSA evidence reviews).

The list of the 490 reports excluded on full text can be found in Table S.7 (supplementary material): 155 reports were excluded for not meeting the inclusion criteria on exposure (that is, not about NPI as implemented in the UK), 107 for not meeting the inclusion criteria on study design (reviews, guidelines or opinion pieces were excluded), 95 for not meeting the inclusion criteria on outcomes (for instance, studies reporting on economic outcomes or health outcomes others than those related to COVID-19 transmission were excluded), 86 for reporting on non-UK studies, 13 for not being about the COVID-19 pandemic, 13 for not meeting the inclusion criteria on publication type (reports other than peer-reviewed articles and preprints were excluded) and 6 for being conducted in health or social care settings (rather than community settings). In addition, 15 were excluded for being duplicate references that had not been previously identified as such (not listed in Table S.7).

Evidence identified

Most of the studies identified were modelling studies (100 out of 151; 66%) (24 to 123) which mainly used stochastic models, although the model used was not always clearly specified. Of

the remaining studies, 2 (1%) were randomised control trials (RCTs) (124, 125), 22 (15%) were individual-level observational studies (10 longitudinal (126 to 135) and 12 cross-sectional (136 to 147) studies), 12 (8%) were population-level observational studies (ecological studies) (148 to 159), 5 (3%) were mixed-methods studies (160 to 164) and 10 (7%) were qualitative studies (165 to 174).

We decided not to use the term 'cohort' or 'case control' and instead categorise the studies as 'longitudinal' to reflect whether a study had followed a group of participants over time (specifying in the data extraction tables whether they were prospective or retrospective, and whether they had a comparator group – see supplementary material). This is because some of the studies identified in this review were natural experiments (175) which did not always fit easily into the conventional categories (RCTs, cohort studies, case control studies, and cross-sectional studies) (176, 177) and did not always provide analytical statistics, whether due to a lack of comparator group, a lack of pre-intervention measurement, or both. In addition, the included studies were conducted during a pandemic, often with limited resources available and with the urgency to have results available as soon as possible, which, combined with issues of poor reporting in some studies, only made the categorisation of studies more challenging.

In terms of NPI categories, 19 studies reported on measures aimed at reducing infection risk at individual level, 80 on measures to identify and isolate those who are infectious or may become infectious, 71 on measures to reduce the numbers of contacts, 9 on measures to protect the most vulnerable, and 12 on travel and border restrictions. Out of the 151 studies, 44 had reported on more than one NPI and are therefore reported across multiple NPI categories (26 to 56, 64, 90, 104, 107, 114, 120, 131, 135 to 138, 149, 165).

Out of the 151 papers identified, 19 were preprints (29, 30, 62 to 64, 66, 68 to 73, 126, 127, 133, 147, 150, 151, 170) (the status of the articles available as preprint was last checked on 22 August 2023, with the data extraction, evidence gap map and synthesis amended accordingly). The remaining were peer-reviewed publications (reports from sources other than peer-reviewed journals or preprint databases were excluded).

Thirty-one out of the 151 studies (21%) had at least one UKHSA or PHE author and, of these, 15 (48%) had a UKHSA or Public Health England (PHE, now UKHSA) first author and 18 (58%) as last author. Excluding modelling studies, 21 out of 51 studies (41%) had at least one UKHSA or PHE author and, of these, 8 (38%) had a UKHSA or PHE first author, and 10 (48%) as last author.

Thirty-nine out of the 151 studies (26%) had at least one author affiliated to a National Institute for Health and Care Research (NIHR) Health Protection Research Unit (HPRU); 23 (45%) excluding modelling studies. The NIHR HPRUs most frequently reported in affiliations were Behavioural Science and Evaluation (19 studies) and Emergency Preparedness and Response (12 studies). To note that out of the 39 studies with an NIHR HPRU affiliation, 17 also had a UKHSA or PHE affiliation.

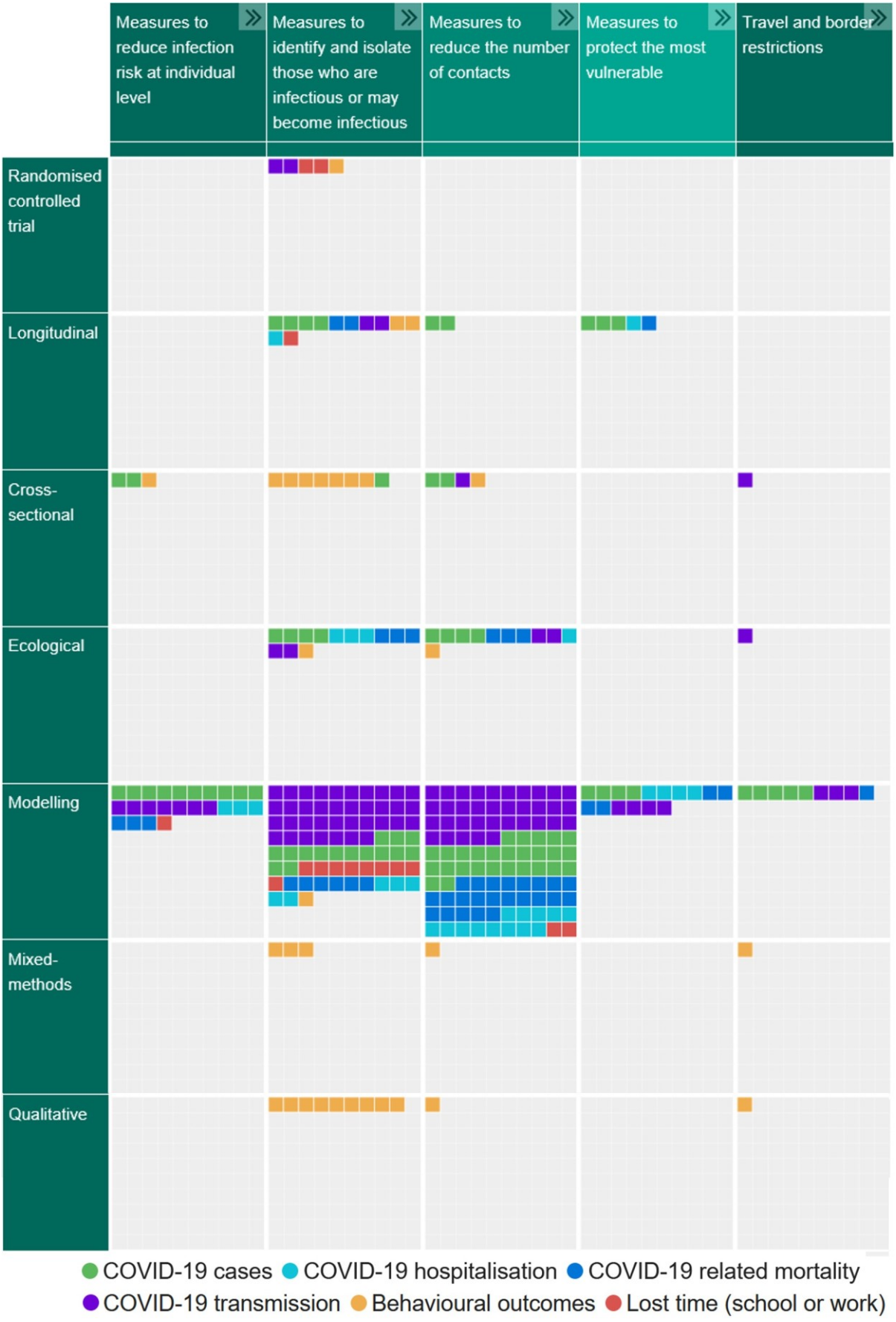
In terms of funding, 14 out of the 151 studies (9%) reported having received funding by the Department of Health and Social Care (DHSC); 12 (24%) excluding modelling studies. Fifteen (10%) studies declared funding from the NIHR, 12 (8%) at least partly from a NIHR HPRU, and

4 (3%) from PHE. In 24 studies (16%), authors declared that they had not received specific funding for the research. In a further 45 studies (30%), authors declared individual grants or other funding not directly linked to the work.

For more details about authorship and funding, see data extraction tables (Tables S.1 to S.6; supplementary material).

The 151 studies identified were mapped onto an interactive evidence gap map generated via EPPI-Mapper (21). In the map, available at Evidence gap map: effectiveness of non-pharmaceutical interventions to reduce transmission of COVID-19 in the UK, the studies are visually displayed by NPI and study design (see screenshot of the map in Figure 1). In this 'mosaic' view, each 'tile' corresponds to one study with the outcome in colour. Studies reporting on more than one NPI or more than one outcome are mapped to more than one 'tile'. (Note on the interactive map: click on 'about' for more information about the map, including how to expand the map and how to view the records).

Figure 1. Screenshot of the evidence gap map representing the number of studies identified for each NPI category and by study design



Measures implemented in the UK to reduce infection risk at individual level

Nineteen studies reporting on effectiveness of NPIs to reduce infection risk at individual level were identified (Table 1). Within this category, face coverings use was the NPI most reported (14 studies), followed by physical distancing (7 studies), ventilation (5 studies), hand hygiene (2 studies) and cleaning (1 study); some studies have reported on more than one NPI and are therefore counted more than once. No evidence was identified on respiratory hygiene.

Of these 19 studies, 16 (84%) were modelling (28, 30, 33, 35, 37, 38, 46, 49, 50, 55, 67, 88, 99, 104, 109, 120). The remaining 3 studies were all cross-sectional (136, 137, 144), suggesting that the studies available on the effectiveness of NPIs implemented in the UK to reduce infection at individual level provide low level of evidence in terms of study design and hierarchy of evidence (no experimental or longitudinal studies identified).

Of the 3 cross-sectional studies, one was an online survey conducted in the UK between November 2020 and May 2021 looking at the association between self-reported use of NPIs and self-reported COVID-19 cases (137), and one was a survey conducted in school staff in Wales looking at self-reported COVID-19 mitigations implemented in schools and COVID-19 cases (136). The last cross-sectional survey, published as a letter and embedded in the wider study COVID-19 Rapid Survey of Adherence to Interventions and Responses [CORSAIR]), reported on self-reported rate of opening windows and perceived effectiveness of ventilation as an NPI (144). All 3 studies had at least one self-reported data (use of NPI and or self-reported COVID-19 infection), therefore introducing further bias to this body of evidence (in addition to it being based on low level of evidence).

All 16 modelling studies reported on outcomes related to COVID-19 transmission and, apart 3 on face coverings (67, 88, 109) and one on ventilation (99), the modelling studies reported on the effectiveness of more than one NPI.

The studies identified for this category can be visualised by NPI and study design in the interactive Evidence gap map: effectiveness of non-pharmaceutical interventions to reduce transmission of COVID-19 in the UK. In the ‘mosaic’ view, each ‘tile’ corresponds to one study with the outcome in colour. Studies reporting on more than one NPI or more than one outcome are mapped to more than one ‘tile’. Click on the arrow next to the NPI category to expand the category you want to explore.

Table 1. List of studies identified on measures implemented in the UK to reduce infection at individual level

Reference	Title	Study design	NPI: individual level	NPI: other	Outcomes
Brooks-Pollock (2021) (28)	Mapping social distancing measures to the reproduction number for COVID-19	Modelling	Face coverings	Contact tracing Limitation of social contacts School closures	COVID-19 transmission
Chen (2021) (30); preprint	Scenario analysis of non-pharmaceutical interventions on global COVID-19 transmissions	Modelling	Face coverings	Limitation of social contacts Lockdown School closures Travel restrictions	COVID-19 cases
Chin (2021) (33)	Effect estimates of COVID-19 non-pharmaceutical interventions are non-robust and highly model-dependent	Modelling	Physical distancing	Isolation of cases Restrictions of large gatherings Lockdown School closures	COVID-19 cases COVID-19 related mortality COVID-19 transmission
Davies (2020) (35)	Effects of non-pharmaceutical interventions on COVID-19 cases, deaths, and demand for hospital services in the UK: a modelling study	Modelling	Physical distancing	Isolation of cases Lockdown School closures Shielding	COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality COVID-19 transmission

Reference	Title	Study design	NPI: individual level	NPI: other	Outcomes
Donnat (2021) (37)	Predicting COVID-19 Transmission to Inform the Management of Mass Events: Model-Based Approach	Modelling	Face coverings	Restrictions of large gatherings	COVID-19 cases
Fitz-Simon (2023) (67)	Understanding the role of mask-wearing during COVID-19 on the island of Ireland	Modelling	Face coverings		COVID-19 hospitalisation
Francis (2023) (137)	Non-pharmaceutical interventions and risk of COVID-19 infection: survey of U.K. public from November 2020 to May 2021	Cross-sectional	Cleaning Face coverings Hand hygiene Physical distancing	Limitation of social contacts	COVID-19 cases
Ghoroghi (2022) (38)	Impact of ventilation and avoidance measures on SARS-CoV-2 risk of infection in public indoor environments	Modelling	Face coverings Hand hygiene Ventilation		COVID-19 transmission

Reference	Title	Study design	NPI: individual level	NPI: other	Outcomes
Heald (2021) (88)	Modelling the impact of the mandatory use of face coverings on public transport and in retail outlets in the UK on COVID-19-related infections, hospital admissions and mortality	Modelling	Face coverings		COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality
Lau (2022) (99)	Predicting the spatio-temporal infection risk in indoor spaces using an efficient airborne transmission model	Modelling	Ventilation		COVID-19 transmission
Li (2021) (46)	Elementary effects analysis of factors controlling COVID-19 infections in computational simulation reveals the importance of social distancing and mask usage	Modelling	Face coverings Physical distancing	Isolation of cases Lockdown	COVID-19 cases

Reference	Title	Study design	NPI: individual level	NPI: other	Outcomes
Marchant (2022) (136)	COVID-19 mitigation measures in primary schools and association with infection and school staff wellbeing: An observational survey linked with routine data in Wales, UK	Cross-sectional	Face coverings Physical distancing	School bubbles	COVID-19 cases
Miller (2022) (104)	Modeling the factors that influence exposure to SARS-CoV-2 on a subway train carriage	Modelling	Face coverings Ventilation		COVID-19 transmission
Moore (2021) (49)	A General Computational Framework for COVID-19 Modelling with Applications to Testing Varied Interventions in Education Environments	Modelling	Face coverings Ventilation	Asymptomatic testing	COVID-19 cases Lost time (school or work)
Novakovic (2022) (50)	The CP-ABM approach for modelling COVID-19 infection	Modelling	Face coverings	Lockdown	COVID-19 cases

Reference	Title	Study design	NPI: individual level	NPI: other	Outcomes
	dynamics and quantifying the effects of non-pharmaceutical interventions				
Panovska-Griffiths (2021) (109)	Modelling the potential impact of mask use in schools and society on COVID-19 control in the UK	Modelling	Face coverings		COVID-19 cases
Smith (2021) (144)	COVID-19 and Ventilation in the Home; Investigating Peoples' Perceptions and Self-Reported Behaviour (the COVID-19 Rapid Survey of Adherence to Interventions and Responses [CORSAIR] Study)	Cross-sectional	Ventilation		Behavioural outcomes
Whitfield (2023) (120)	Modelling the impact of non-pharmaceutical interventions on workplace transmission of SARS-	Modelling	Physical distancing	Asymptomatic testing Isolation of cases Isolation of contacts Cohorting	COVID-19 transmission

Reference	Title	Study design	NPI: individual level	NPI: other	Outcomes
	CoV-2 in the home-delivery sector			Workplace closure or work from home	
Ying (2021) (55)	Modelling COVID-19 transmission in supermarkets using an agent-based model	Modelling	Face coverings Physical distancing	Limitation of social contacts	COVID-19 cases

Measures implemented in the UK to identify and isolate those who are infectious or may become infectious

Eighty studies reported on effectiveness of NPIs to identify and isolate those who are infectious or may become infectious (Table 2). Within this category, asymptomatic testing was the NPI most reported (30 studies), followed by contact tracing (27 studies), isolation of cases (21 studies), test and release strategies (14 studies), isolation of contacts (10 studies) and symptomatic testing (7 studies). Some studies have reported on more than one NPI and are therefore counted more than once.

Of these 80 studies, 46 (58%) were modelling (26 to 29, 31 to 33, 35,39 to 47, 49, 51, 53, 54, 56, 59, 63, 64, 66, 68, 69, 71, 73, 80 to 84, 87, 89, 90, 101, 102, 107, 112, 114, 115, 120, 121). There were 2 (3%) RCTs (124, 125) and 14 (18%) individual-level observational studies (7 longitudinal (126, 128 to 133) and 7 cross-sectional (138, 139, 141 to 143, 145, 146)). Of the remaining studies, 6 (8%) were ecological (149, 150, 152, 153, 156, 158), 3 (4%) mixed-methods (160, 162, 163) and 9 (11%) qualitative (165, 167 to 174).

Whilst the level of evidence (in terms of study design and hierarchy of evidence) available for this category of NPI is slightly higher than for the other NPI categories due to the presence of the RCTs and individual-level observational studies (longitudinal and cross-sectional studies), it remains mainly based on modelling, ecological, mixed-methods and qualitative studies (80% for these 4 study designs). In terms of study design and traditional hierarchy of evidence, it is nonetheless worth highlighting the use of synthetic control methods in 3 of the 6 ecological studies (150, 152, 158) to estimate causal effects in natural experiments through statistical methods (178). On the other hand, 4 studies that assessed the implementation of testing strategies as outbreak control in different settings (prisons (130, 131), elite sporting events (126) and key workers (129) – no control groups) were classified as prospective longitudinal studies, and 2 natural experiments (delay in contact tracing due to a coding error) were classified as retrospective longitudinal studies with control group (132,133) (groups with delay in contact tracing, and a natural occurring control group without delay). Of the 7 longitudinal studies, only one was prospective with a control group (128).

Most of the higher-level studies identified in this category reported on test and release strategies, including both RCTs (124, 125) and 2 of the prospective longitudinal studies (128, 129). Test and release strategies consisted of daily testing (usually based on antigen testing) with the aim to release cases and contacts earlier from isolation (these are different from the test to release strategies implemented for returning travellers). The acceptability and feasibility of these strategies were first assessed in the wider community in England between December 2020 and January 2021 (128, 142, 167) and in key workers in Liverpool between December 2020 and August 2021 (129). These proof-of concepts were then followed by the 2 RCTs: one conducted in English secondary school and educational settings between April and June 2021 (124) – and a linked qualitative study (168) – and one in the wider community in England between April and July 2021 (125) – and a linked qualitative study (169). These studies

assessed the effectiveness of test and release strategies in relation to COVID-19 transmission, but also in terms of acceptability, feasibility and impact on school or work attendance. Six modelling studies also looked at the effectiveness on these strategies (31, 44, 63, 66, 69, 112), reporting on COVID-19 transmission and days spent at school or work rather than in isolation.

Regarding other NPIs in this category, one longitudinal study (preprint) reported on the effectiveness of daily asymptomatic testing to enable sporting events (126) whilst the other studies identified were mainly modelling studies reporting on effectiveness of contact tracing, asymptomatic testing and isolation of cases and contacts in reducing COVID-19 transmission. It is nonetheless worth highlighting that a number of studies (mainly mixed-methods and qualitative studies) focused on behavioural outcomes such as compliance, adherence, perceptions and attitudes in relation to asymptomatic testing (139, 141, 145, 160, 162, 163, 165, 172 to 174), contact tracing (138, 143, 170, 171), of which one preprint (170), and symptomatic testing (146).

To note that studies were coded as contact tracing if the aim was to assess the effectiveness of the process of identifying contacts and potential cases, while studies were coded as testing or isolation if the aim was to assess those. However, and depending on the studies, the distinction was not always clear because isolation and or symptomatic testing could be implicit in the contact tracing intervention being evaluated which may have resulted in some inconsistencies.

The studies identified for this category can be visualised by NPI and study design in the interactive Evidence gap map: effectiveness of non-pharmaceutical interventions to reduce transmission of COVID-19 in the UK. In the ‘mosaic’ view, each ‘tile’ corresponds to one study with the outcome in colour. Studies reporting on more than one NPI or more than one outcome are mapped to more than one ‘tile’. Click on the arrow next to the NPI category to expand the category you want to explore.

Table 2. List of studies identified on measures implemented in the UK to identify and isolate those who are infectious or may become infectious

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
Almagor (2020) (26)	Exploring the effectiveness of a COVID-19 contact tracing app using an agent-based model	Modelling	Contact tracing Symptomatic testing		COVID-19 transmission
Alsing (2020) (29); preprint	Containing COVID-19 outbreaks with spatially targeted short-term lockdowns and mass-testing	Modelling	Asymptomatic testing	Lockdown	COVID-19 cases COVID-19 transmission
Bassolas (2022) (59)	Optimizing the mitigation of epidemic spreading through targeted adoption of contact tracing apps	Modelling	Contact tracing		COVID-19 transmission
Bays (2021) (27)	Insights gained from early modelling of COVID-19 to inform the management of outbreaks in UK prisons	Modelling	Isolation of cases	Cohorting Shielding	COVID-19 hospitalisation COVID-19 transmission
Bays (2022) (63); preprint	Mitigating isolation: further comparing the effect of LFD testing for early release from self-isolation for COVID-19 cases	Modelling	Test and release strategies		COVID-19 transmission Lost time (school or work)
Blackmore (2022) (130)	Testing for COVID-19 during an outbreak within a large UK prison: an evaluation of mass testing to inform outbreak control	Longitudinal	Asymptomatic testing		COVID-19 cases

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
Blake (2021) (160)	Perceptions and experiences of the University of Nottingham pilot SARS-CoV-2 asymptomatic testing service: a mixed-methods study	Mixed methods	Asymptomatic testing		Behavioural outcomes
Blake (2021) (165)	Students' views towards SARS-CoV-2 mass asymptomatic testing, social distancing and self-isolation in a university setting during the COVID-19 pandemic: A qualitative study	Qualitative	Asymptomatic testing Isolation of cases Isolation of contacts	Limitation of social contacts	Behavioural outcomes
Brooks-Pollock (2021) (28)	Mapping social distancing measures to the reproduction number for COVID-19	Modelling	Contact tracing	Face coverings Limitation of social contacts School closures	COVID-19 transmission
Chin (2021) (33)	Effect estimates of COVID-19 non-pharmaceutical interventions are non-robust and highly model-dependent	Modelling	Isolation of cases	Physical distancing Restrictions of large gatherings Lockdown School closures	COVID-19 cases COVID-19 related mortality COVID-19 transmission

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
Coleman (2022) (131)	Implementation of novel and conventional outbreak control measures in managing COVID-19 outbreaks in a large UK prison	Longitudinal	Isolation of cases Isolation of contacts	Cohorting Shielding	COVID-19 cases
Cuesta (2021) (64); preprint	Vaccinations or Non-Pharmaceutical Interventions: Safe Reopening of Schools in England	Modelling	Isolation of cases Isolation of contacts	Limitation of social contacts	COVID-19 cases COVID-19 related mortality
Davies (2020) (35)	Effects of non-pharmaceutical interventions on COVID-19 cases, deaths, and demand for hospital services in the UK: a modelling study	Modelling	Isolation of cases	Physical distancing Lockdown School closures Shielding	COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality COVID-19 transmission
Davies (2022) (126); preprint	Risk assessed daily contact testing enabling elite sporting events during the COVID-19 pandemic: a prospective cohort study	Longitudinal	Asymptomatic testing		COVID-19 cases

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
Davis (2021) (80)	Contact tracing is an imperfect tool for controlling COVID-19 transmission and relies on population adherence	Modelling	Contact tracing		COVID-19 cases COVID-19 transmission
Denford (2021) (167)	Engagement With Daily Testing Instead of Self-Isolating in Contacts of Confirmed Cases of SARS-CoV-2: A Qualitative Analysis	Qualitative	Test and release strategies		Behavioural outcomes
Denford (2022) (168)	Feasibility and acceptability of daily testing at school as an alternative to self-isolation following close contact with a confirmed case of COVID-19: a qualitative analysis	Qualitative	Test and release strategies		Behavioural outcomes
Denford (2022) (169)	A qualitative process analysis of daily contact testing as an alternative to self-isolation following close contact with a confirmed carrier of SARS-CoV-2	Qualitative	Test and release strategies		Behavioural outcomes
Drakesmith (2022) (81)	Cost-effectiveness of a whole-area testing pilot of asymptomatic SARS-CoV-2 infections with lateral flow devices: a modelling and economic analysis study	Modelling	Asymptomatic testing		COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
Endo (2020) (82)	Implication of backward contact tracing in the presence of overdispersed transmission in COVID-19 outbreaks	Modelling	Contact tracing		COVID-19 transmission
Farkas (2021) (83)	Assessing the impact of (Self)-quarantine through a basic model of infectious disease dynamics	Modelling	Isolation of cases		COVID-19 cases COVID-19 transmission
Ferretti (2021) (66); preprint	Modelling the effectiveness and social costs of daily lateral flow antigen tests versus quarantine in preventing onward transmission of COVID-19 from traced contacts	Modelling	Test and release strategies		COVID-19 transmission Lost time (school or work)
Fetzer (2021) (132)	Measuring the scientific effectiveness of contact tracing: Evidence from a natural experiment	Longitudinal	Contact tracing		COVID-19 cases COVID-19 related mortality
Findlater (2022) (133); preprint	Evaluating the impact on health outcomes of an event that resulted in a delay in contact tracing of COVID-19 cases	Longitudinal	Contact tracing		COVID-19 hospitalisation COVID-19 related mortality COVID-19 transmission

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
French (2022) (162)	Low uptake of COVID-19 lateral flow testing among university students: a mixed methods evaluation	Mixed methods	Asymptomatic testing		Behavioural outcomes
Fyles (2021) (84)	Using a household-structured branching process to analyse contact tracing in the SARS-CoV-2 pandemic	Modelling	Contact tracing		COVID-19 transmission Behavioural outcomes
Gianino (2021) (149)	Evaluation of the Strategies to Control COVID-19 Pandemic in Four European Countries	Ecological	Contact tracing	Travel restrictions Limitation of social contacts School closures Workplace closure or work from home	COVID-19 transmission
Gillam (2021) (141)	Norwich COVID-19 testing initiative pilot: evaluating the feasibility of asymptomatic testing on a university campus	Cross-sectional	Asymptomatic testing		Behavioural outcomes
Goldberg (2021) (87)	Increasing efficacy of contact-tracing applications by user referrals and stricter quarantining	Modelling	Contact tracing		COVID-19 hospitalisation
Gosce (2020) (39)	Modelling SARS-COV2 Spread in London: Approaches to Lift the Lockdown	Modelling	Asymptomatic testing	Lockdown Shielding	COVID-19 cases

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
					COVID-19 related mortality COVID-19 transmission
Grassly (2020) (40)	Comparison of molecular testing strategies for COVID-19 control: a mathematical modelling study	Modelling	Asymptomatic testing Contact tracing Isolation of cases Isolation of contacts Symptomatic testing		COVID-19 transmission
He (2021) (89)	Effectiveness and resource requirements of test, trace and isolate strategies for COVID in the UK	Modelling	Contact tracing		COVID-19 transmission
Hellewell (2020) (41)	Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts	Modelling	Contact tracing Isolation of cases		COVID-19 transmission
Hemani (2021) (68); preprint	Modelling pooling strategies for SARS-CoV-2 testing in a university setting [version 1; peer review: awaiting peer review]	Modelling	Asymptomatic testing		COVID-19 cases

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
Hill (2021) (90)	Modelling SARS-CoV-2 transmission in a UK university setting	Modelling	Asymptomatic testing Contact tracing Isolation of cases		COVID-19 cases
Hill (2021) (42)	A network modelling approach to assess non-pharmaceutical disease controls in a worker population: An application to SARS-CoV-2	Modelling	Contact tracing	Limitation of social contacts Workplace closures or work from home	COVID-19 transmission
Hirst (2021) (163)	Feasibility and Acceptability of Community Coronavirus Disease 2019 Testing Strategies (FACTS) in a University Setting	Mixed methods	Asymptomatic testing		Behavioural outcomes
Hounsome (2022) (150); preprint	Epidemiological impact of a large number of incorrect negative SARS-CoV-2 test results in South West England during September and October 2021	Ecological	Symptomatic testing		COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality
Kendall (2020) (152)	Epidemiological changes on the Isle of Wight after the launch of the NHS Test and Trace programme: a preliminary analysis	Ecological	Contact tracing		COVID-19 cases

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
					COVID-19 transmission
Kendall (2023) (153)	Epidemiological impacts of the NHS COVID-19 app in England and Wales throughout its first year	Ecological	Contact tracing		COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality Behavioural outcomes
Kucharski (2020) (43)	Effectiveness of isolation, testing, contact tracing, and physical distancing on reducing transmission of SARS-CoV-2 in different settings: a mathematical modelling study	Modelling	Asymptomatic testing Contact tracing Isolation of cases Isolation of contacts	Limitation of social contacts	COVID-19 transmission
Kunzmann (2022) (31)	The 'how' matters: A simulation-based assessment of the potential contributions of LFD tests for school reopening in England	Modelling	Asymptomatic testing Test and release strategies	School bubbles	COVID-19 transmission Lost time (school or work)

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
Leng (2022) (44)	Quantifying pupil-to-pupil SARS-CoV-2 transmission and the impact of lateral flow testing in English secondary schools	Modelling	Asymptomatic testing Isolation of contacts Test and release strategies		COVID-19 transmission Lost time (school or work)
Leng (2022) (45)	Assessing the impact of lateral flow testing strategies on within-school SARS-CoV-2 transmission and absences: A modelling study	Modelling	Asymptomatic testing	School bubbles	COVID-19 transmission Lost time (school or work)
Leng (2022) (101)	The effect of notification window length on the epidemiological impact of COVID-19 contact tracing mobile applications	Modelling	Contact tracing		COVID-19 transmission
Li (2021) (46)	Elementary effects analysis of factors controlling COVID-19 infections in computational simulation reveals the importance of social distancing and mask usage	Modelling	Isolation of cases	Face coverings Physical distancing Lockdown	COVID-19 cases
Love (2022) (128)	The acceptability of testing contacts of confirmed COVID-19 cases using serial, self-administered lateral flow devices as an alternative to self-isolation	Longitudinal	Test and release strategies		COVID-19 transmission Behavioural outcomes

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
Love (2022) (125)	Daily use of lateral flow devices by contacts of confirmed COVID-19 cases to enable exemption from isolation compared with standard self-isolation to reduce onward transmission of SARS-CoV-2 in England: a randomised, controlled, non-inferiority trial	RCT	Test and release strategies		COVID-19 transmission Behavioural outcomes Lost time (school or work)
Lovell-Read (2022) (47)	Estimating local outbreak risks and the effects of non-pharmaceutical interventions in age-structured populations: SARS-CoV-2 as a case study	Modelling	Isolation of cases	Limitation of social contacts School closures Workplace closure or work from home	COVID-19 transmission
Lucas (2021) (102)	Engagement and adherence trade-offs for SARS-CoV-2 contact tracing	Modelling	Isolation of cases		COVID-19 transmission
Marchant (2021) (139)	Determining the acceptability of testing contacts of confirmed COVID-19 cases to improve secondary case ascertainment	Cross-sectional	Asymptomatic testing		COVID-19 cases Behavioural outcomes
Marsden (2022) (129)	Daily testing of contacts of SARS-CoV-2 infected cases as an alternative to	Longitudinal	Test and release strategies		Behavioural outcomes Lost time

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
	quarantine for key workers in Liverpool: A prospective cohort study				(school or work)
Marshall (2022) (170); preprint	Public perceptions and interactions with UK COVID-19 Test, Trace and Isolate policies, and implications for pandemic infectious disease modelling [version 1; peer review: awaiting peer review]	Qualitative	Contact tracing		Behavioural outcomes
Martin (2021) (142)	Engagement with daily testing instead of self-isolating in contacts of confirmed cases of SARS-CoV-2	Cross-sectional	Test and release strategies		Behavioural outcomes
Moore (2021) (49)	A General Computational Framework for COVID-19 Modelling with Applications to Testing Varied Interventions in Education Environments	Modelling	Asymptomatic testing	Face coverings Ventilation	COVID-19 cases Lost time (school or work)
Nadim (2021) (107)	Short-term predictions and prevention strategies for COVID-19: A model-based study	Modelling	Isolation of cases Isolation of contacts		COVID-19 transmission
O'Donnell (2022) (171)	Widening or narrowing inequalities? The equity implications of digital tools to support COVID-19 contact tracing: A qualitative study	Qualitative	Contact tracing		Behavioural outcomes

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
Panchal (2021) (143)	Analysis of the factors affecting the adoption and compliance of the NHS COVID-19 mobile application: A national cross-sectional survey in England	Cross-sectional	Contact tracing		Behavioural outcomes
Quilty (2021) (112)	Quarantine and testing strategies in contact tracing for SARS-CoV-2: a modelling study	Modelling	Test and release strategies		COVID-19 transmission
Quilty (2022) (69); preprint	Test to release from isolation after testing positive for SARS-CoV-2	Modelling	Test and release strategies		COVID-19 transmission Lost time (school or work)
Rice (2020) (51)	Effect of school closures on mortality from coronavirus disease 2019: old and new predictions	Modelling	Isolation of cases Isolation of contacts	Limitation of social contacts School closures Shielding	COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality
Robin (2022) (172)	Local Community Response to Mass Asymptomatic COVID-19 Testing in Liverpool, England: Social Media Analysis	Qualitative	Asymptomatic testing		Behavioural outcomes

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
Sandmann (2020) (114)	Optimizing Benefits of Testing Key Workers for Infection with SARS-CoV-2: A Mathematical Modeling Analysis	Modelling	Asymptomatic testing Symptomatic testing		COVID-19 transmission Lost time (school or work)
Silva (2023) (32)	The role of regular asymptomatic testing in reducing the impact of a COVID-19 wave	Modelling	Asymptomatic testing Contact tracing Isolation of cases Symptomatic testing		COVID-19 cases
Skittrall (2021) (115)	SARS-CoV-2 screening: Effectiveness and risk of increasing transmission	Modelling	Asymptomatic testing		COVID-19 transmission
Smith (2021) (138)	Adherence to the test, trace, and isolate system in the UK: Results from 37 nationally representative surveys	Cross-sectional	Contact tracing Isolation of cases Symptomatic testing		Behavioural outcomes
Smith (2022) (145)	Who is engaging with lateral flow testing for COVID-19 in the UK? The COVID-19 Rapid Survey of Adherence to Interventions and Responses (CORSAIR) study	Cross-sectional	Asymptomatic testing		Behavioural outcomes

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
Stocks (2021) (71); preprint	Limited impact of contact tracing in a University setting for COVID-19 due to asymptomatic transmission and social distancing	Modelling	Contact tracing		COVID-19 transmission
Wallis (2020) (146)	Experience of a novel community testing programme for COVID-19 in London: Lessons learnt	Cross-sectional	Symptomatic testing		Behavioural outcomes
Wanat (2021) (173)	Perceptions on undertaking regular asymptomatic self-testing for COVID-19 using lateral flow tests: A qualitative study of university students and staff	Qualitative	Asymptomatic testing		Behavioural outcomes
Warne (2021) (73); preprint	Feasibility and efficacy of mass testing for SARS-CoV-2 in a UK university using swab pooling and PCR	Modelling	Asymptomatic testing		COVID-19 cases COVID-19 transmission
Watson (2022) (174)	How do we engage people in testing for COVID-19? A rapid qualitative evaluation of a testing programme in schools, GP surgeries and a university	Qualitative	Asymptomatic testing		Behavioural outcomes
Wells (2020) (53)	Disease control across urban-rural gradients	Modelling	Lockdown Contact tracing		COVID-19 transmission

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
Whitfield (2023) (120)	Modelling the impact of non-pharmaceutical interventions on workplace transmission of SARS-CoV-2 in the home-delivery sector	Modelling	Asymptomatic testing Isolation of cases Isolation of contacts	Physical distancing Cohorting Workplace closure or work from home	COVID-19 transmission
Woodhouse (2022) (54)	Alternative COVID-19 mitigation measures in school classrooms: analysis using an agent-based model of SARS-CoV-2 transmission	Modelling	Asymptomatic testing	School bubbles	COVID-19 transmission Lost time (school or work)
Wymant (2021) (156)	The epidemiological impact of the NHS COVID-19 app	Ecological	Contact tracing		COVID-19 cases COVID-19 related mortality
Yakob (2021) (121)	Isolation thresholds for curbing SARS-CoV-2 resurgence	Modelling	Isolation of cases		COVID-19 transmission
Young (2021) (124)	Daily testing for contacts of individuals with SARS-CoV-2 infection and attendance and SARS-CoV-2 transmission in English secondary schools and colleges: an open-label, cluster-randomised trial	RCT	Test and release strategies		COVID-19 transmission Lost time (school or work)

Reference	Title	Study design	NPI: identify or isolate	NPI: other	Outcomes
Zhang (2022) (56)	Evaluating the impact of stay-at-home and quarantine measures on COVID-19 spread	Modelling	Isolation of cases Isolation of contacts		COVID-19 transmission
Zhang (2022) (158)	Impact of community asymptomatic rapid antigen testing on COVID-19 related hospital admissions: synthetic control study	Ecological	Asymptomatic testing		COVID-19 hospitalisation

Measures implemented in the UK to reduce the number of contacts

Seventy-one studies reporting on effectiveness of NPIs to reduce the number of contacts were identified (Table 3). Within this category, lockdown was the NPI most reported (36 studies), followed by school closures (17 studies), limitation of social contacts (17 studies), school bubbles (5 studies), workplace closure or work from home (5 studies), tiered restrictions (4 studies), restrictions of large gatherings (3 studies), cohorting (3 studies) and hospitality settings closure (one study).

There was an important overlap between the different NPIs implemented to reduce the number of contacts. For instance, the lack of evidence identified on the effectiveness of hospitality settings closure (only one study) can be explained by the fact that some studies considered settings closures as part of lockdown and therefore only reported on effectiveness of lockdown. Limitation of social contacts was also sometimes included under lockdown, although some studies reported on specific measures implemented in the UK such as Christmas household bubbles (91), formation of household support bubbles (92) or social bubbles (100).

To note that studies reporting on cohorting in healthcare settings were excluded, including measures such as cohorting of staff or residents in adult and social care settings. In community settings, cohorting was implemented for instance in the workplace (120) and in prisons where reverse cohorting was applied to keep new prisoners apart from other prisoners (131,179). School bubbles are also a form of cohorting, although in this mapping it was decided to separate them out in order to be able to identify school-specific studies.

Of these 71 studies, 57 (80%) were modelling (24, 25, 27 to 31, 33 to 37, 39, 42, 43, 45 to 48, 50 to 55, 57, 58, 62, 64, 65, 74 to 77, 85, 86, 91 to 98, 100, 103, 105, 106, 108, 110, 111, 113, 118 to 120, 122, 123). Two (3%) studies were prospective longitudinal (131, 135) and 3 (4%) were cross-sectional (136, 137, 140). Of the remaining studies, there were 7 (10%) ecological studies (148, 149, 151, 154, 155, 157, 159), of which one used the synthetic control method (157), as well as one mixed-methods (161) and one qualitative (165) studies. No experimental studies reporting on measures to reduce the number of contacts were identified.

Of the 2 prospective longitudinal studies, one was a surveillance study assessing the impact of school closures and lockdown on COVID-19 cases in children in England (135), and one reported on the implementation of outbreak control measures, including isolation of cases and of contacts, in a UK prison (131).

One of the 3 cross-sectional studies used data from the longitudinal behavioural survey CoMix to assess change in contact patterns associated with lockdown and did further statistical analyses to estimate the corresponding change in reproduction number (140). The 2 other cross-sectional studies were surveys which reported on the associations between a range of self-reported NPIs and COVID-19 outcomes: one was an online survey conducted in the UK between November 2020 and May 2021 looking at the association between self-reported use of NPIs, including limitations of social contacts, and self-reported COVID-19 infections (137), and

one was a survey conducted in school staff in Wales looking at self-reported COVID-19 mitigations implemented in schools, including school bubbles, and COVID-19 cases (136). Both studies also reported on NPIs such as face coverings use and physical distancing and were therefore also included in the section on measures to reduce infection risk at individual level.

All modelling studies reported on outcomes related to COVID-19 transmission, with the exception of 3 which also assessed the impact of school bubbles on school attendance (31, 45, 54).

The mixed-method and the qualitative studies both reported on behavioural outcomes: one on the feasibility and acceptability of a protocol to allow reopening of large live mass events (161), and one on students' perceptions of limitation of social contacts (as well as asymptomatic testing and isolation of contacts, and therefore also reported in the corresponding section) (165).

The studies identified for this category can be visualised by NPI and study design in the interactive Evidence gap map: effectiveness of non-pharmaceutical interventions to reduce transmission of COVID-19 in the UK. In the 'mosaic' view, each 'tile' corresponds to one study with the outcome in colour. Studies reporting on more than one NPI or more than one outcome are mapped to more than one 'tile'. Click on the arrow next to the NPI category to expand the category you want to explore.

Table 3. List of studies identified on measures implemented in the UK to reduce the number of contacts

Reference	Title	Study design	NPI: reduced contacts	NPI: other	Outcomes
Abernethy (2022) (25)	Optimal COVID-19 lockdown strategies in an age-structured SEIR model of Northern Ireland	Modelling	Lockdown		COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality COVID-19 transmission
Albi (2021) (24)	Modelling lockdown measures in epidemic outbreaks using selective socio-economic containment with uncertainty	Modelling	Lockdown		COVID-19 transmission
Alsing (2020) (29); preprint	Containing COVID-19 outbreaks with spatially targeted short-term lockdowns and mass-testing	Modelling	Lockdown	Asymptomatic testing	COVID-19 cases COVID-19 transmission
Arnold (2022) (57)	Estimating the effects of lockdown timing on COVID-19 cases and deaths in England: A counterfactual modelling study	Modelling	Lockdown		COVID-19 cases COVID-19 related mortality
Aspinall (2020) (62); preprint	Quantifying threat from COVID-19 infection hazard in Primary Schools in England	Modelling	School closures		COVID-19 cases
Banks (2022) (58)	ScoVMod – a spatially explicit mobility and deprivation adjusted model of first wave COVID-19 transmission dynamics	Modelling	Lockdown		COVID-19 related mortality

Reference	Title	Study design	NPI: reduced contacts	NPI: other	Outcomes
Bays (2021) (27)	Insights gained from early modelling of COVID-19 to inform the management of outbreaks in UK prisons	Modelling	Cohorting	Isolation of cases Shielding	COVID-19 hospitalisation COVID-19 transmission
Bernal (2021) (148)	The impact of social and physical distancing measures on COVID-19 activity in England: findings from a multi-tiered surveillance system	Ecological	Lockdown		COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality
Biglarbeigi (2021) (75)	Sensitivity analysis of the infection transmissibility in the UK during the COVID-19 pandemic	Modelling	Workplace closure or work from home		COVID-19 transmission
Bittihn (2021) (74)	Local measures enable COVID-19 containment with fewer restrictions due to cooperative effects	Modelling	Tiered restrictions		COVID-19 transmission
Blake (2021) (165)	Students' views towards sars-cov-2 mass asymptomatic testing, social distancing and self-isolation in a university setting during the COVID-19 pandemic: A qualitative study	Qualitative	Limitation of social contacts	Asymptomatic testing Isolation of cases Isolation of contacts	Behavioural outcomes
Boldea (2023) (76)	Disentangling the effect of measures, variants, and vaccines on SARS-CoV-2 infections in England: A dynamic intensity model	Modelling	Lockdown		COVID-19 cases

Reference	Title	Study design	NPI: reduced contacts	NPI: other	Outcomes
Brooks-Pollock (2021) (28)	Mapping social distancing measures to the reproduction number for COVID-19	Modelling	Limitation of social contacts School closures	Face coverings Contact tracing	COVID-19 transmission
Cheetham (2021) (77)	Determining the level of social distancing necessary to avoid future COVID-19 epidemic waves: a modelling study for North East London	Modelling	Limitation of social contacts		COVID-19 hospitalisation COVID-19 related mortality
Chen (2021) (30); preprint	Scenario analysis of non-pharmaceutical interventions on global COVID-19 transmissions	Modelling	Limitation of social contacts Lockdown School closures	Face coverings Travel restrictions	COVID-19 cases
Chin (2021) (33)	Effect estimates of COVID-19 non-pharmaceutical interventions are non-robust and highly model-dependent	Modelling	Restrictions of large gatherings Lockdown School closures	Physical distancing Isolation of cases	COVID-19 cases COVID-19 related mortality COVID-19 transmission
Coleman (2022) (131)	Implementation of novel and conventional outbreak control measures in managing COVID-19 outbreaks in a large UK prison	Longitudinal	Cohorting	Isolation of cases Isolation of contacts Shielding	COVID-19 cases
Cuesta (2021) (64); preprint	Vaccinations or Non-Pharmaceutical Interventions: Safe Reopening of Schools in England	Modelling	Limitation of social contacts	Isolation of cases Isolation of contacts	COVID-19 cases COVID-19 related mortality

Reference	Title	Study design	NPI: reduced contacts	NPI: other	Outcomes
Dallera (2022) (161)	Evaluating the feasibility and acceptability of a safety protocol to mitigate SARS-CoV-2 transmission risks when participating in full-capacity live mass events: a cross-sectional survey and interview-based study	Mixed methods	Restrictions of large gatherings		Behavioural outcomes
Davies (2021) (34)	Association of tiered restrictions and a second lockdown with COVID-19 deaths and hospital admissions in England: a modelling study	Modelling	Lockdown School closures Tiered restrictions		COVID-19 hospitalisation COVID-19 related mortality COVID-19 transmission
Davies (2020) (35)	Effects of non-pharmaceutical interventions on COVID-19 cases, deaths, and demand for hospital services in the UK: a modelling study	Modelling	Lockdown School closures	Physical distancing Isolation of cases Shielding	COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality COVID-19 transmission
Didelot (2023) (65)	Model design for non-parametric phylodynamic inference and applications to pathogen surveillance	Modelling	Lockdown		COVID-19 transmission
Dong (2022) (36)	Deep recurrent reinforced learning model to compare the efficacy of targeted local versus national measures on the spread of COVID-19 in the UK	Modelling	Limitation of social contacts Lockdown School closures	Travel restrictions	COVID-19 cases COVID-19 related mortality

Reference	Title	Study design	NPI: reduced contacts	NPI: other	Outcomes
Donnat (2021) (37)	Predicting COVID-19 Transmission to Inform the Management of Mass Events: Model-Based Approach	Modelling	Restrictions of large gatherings	Face coverings	COVID-19 cases
Francis (2023) (137)	Non-pharmaceutical interventions and risk of COVID-19 infection: survey of U.K. public from November 2020 – May 2021	Cross-sectional	Limitation of social contacts	Cleaning Face coverings Hand hygiene Physical distancing	COVID-19 cases
Galanis (2021) (85)	The effectiveness of non-pharmaceutical interventions in reducing the COVID-19 contagion in the UK, an observational and modelling study	Modelling	Lockdown		COVID-19 cases COVID-19 transmission
Gianino (2021) (149)	Evaluation of the Strategies to Control COVID-19 Pandemic in Four European Countries	Ecological	Limitation of social contacts School closures Workplace closure or work from home	Contact tracing Travel restrictions	COVID-19 transmission
Gog (2021) (86)	Epidemic interventions: insights from classic results	Modelling	Lockdown		COVID-19 transmission
Gosce (2020) (39)	Modelling SARS-COV2 Spread in London: Approaches to Lift the Lockdown	Modelling	Lockdown	Asymptomatic testing Shielding	COVID-19 cases COVID-19 related mortality COVID-19 transmission

Reference	Title	Study design	NPI: reduced contacts	NPI: other	Outcomes
Hill (2021) (42)	A network modelling approach to assess non-pharmaceutical disease controls in a worker population: An application to SARS-CoV-2	Modelling	Limitation of social contacts Workplace closure or work from home	Contact tracing	COVID-19 transmission
Hill (2023) (91)	Modelling the epidemiological implications for SARS-CoV-2 of Christmas household bubbles in England	Modelling	Limitation of social contacts		COVID-19 cases
Hilton (2022) (92)	A computational framework for modelling infectious disease policy based on age and household structure with applications to the COVID-19 pandemic	Modelling	Limitation of social contacts		COVID-19 transmission
Hinch (2022) (93)	Estimating SARS-CoV-2 variant fitness and the impact of interventions in England using statistical and geo-spatial agent-based models	Modelling	Lockdown		COVID-19 cases COVID-19 related mortality
Hunter (2021) (151); preprint	The Impact of the November 2020 English National Lockdown on COVID-19 case counts	Ecological	Lockdown		COVID-19 cases COVID-19 transmission
Jarvis (2020) (140)	Quantifying the impact of physical distance measures on the transmission of COVID-19 in the UK	Cross-sectional	Lockdown		COVID-19 transmission Behavioural outcomes
Jeffrey (2020) (159)	Anonymised and aggregated crowd level mobility data from mobile phones suggests that initial compliance with COVID-19 social distancing	Ecological	Lockdown		Behavioural outcomes

Reference	Title	Study design	NPI: reduced contacts	NPI: other	Outcomes
	interventions was high and geographically consistent across the UK				
Kaiser (2021) (95)	Social network-based cohorting to reduce the spread of SARS-CoV-2 in secondary schools: A simulation study in classrooms of four European countries	Modelling	School bubbles		COVID-19 transmission
Kamiya (2022) (94)	Estimating time-dependent infectious contact: a multi-strain epidemiological model of SARS-CoV-2 on the island of Ireland	Modelling	Lockdown		COVID-19 hospitalisation COVID-19 transmission
Keeling (2021) (96)	Precautionary breaks: Planned, limited duration circuit breaks to control the prevalence of SARS-CoV2 and the burden of COVID-19 disease	Modelling	Lockdown		COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality
Keeling (2021) (97)	The impact of school reopening on the spread of COVID-19 in England	Modelling	School closures		COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality COVID-19 transmission
Kucharski (2020) (43)	Effectiveness of isolation, testing, contact tracing, and physical distancing on reducing transmission of	Modelling	Limitation of social contacts	Asymptomatic testing Contact tracing	COVID-19 transmission

Reference	Title	Study design	NPI: reduced contacts	NPI: other	Outcomes
	SARS-CoV-2 in different settings: a mathematical modelling study			Isolation of cases Isolation of contacts	
Kunzmann (2022) (31)	The 'how' matters: A simulation-based assessment of the potential contributions of LFD tests for school reopening in England	Modelling	School bubbles	Asymptomatic testing Test and release strategies	COVID-19 transmission Lost time (school or work)
Laydon (2021) (98)	Modelling the impact of the tier system on SARS-CoV-2 transmission in the UK between the first and second national lockdowns	Modelling	Tiered restrictions		COVID-19 transmission
Leng (2020) (100)	The effectiveness of social bubbles as part of a COVID-19 lockdown exit strategy, a modelling study	Modelling	Limitation of social contacts		COVID-19 related mortality COVID-19 transmission
Leng (2022) (45)	Assessing the impact of lateral flow testing strategies on within-school SARS-CoV-2 transmission and absences: A modelling study	Modelling	School bubbles	Asymptomatic testing	COVID-19 transmission Lost time (school or work)
Li (2021) (46)	Elementary effects analysis of factors controlling COVID-19 infections in computational simulation reveals the importance of social distancing and mask usage	Modelling	Lockdown	Face coverings Physical distancing Isolation of cases	COVID-19 cases

Reference	Title	Study design	NPI: reduced contacts	NPI: other	Outcomes
Lovell-Read (2022) (47)	Estimating local outbreak risks and the effects of non-pharmaceutical interventions in age-structured populations: SARS-CoV-2 as a case study	Modelling	Limitation of social contacts School closures Workplace closure or work from home	Isolation of cases	COVID-19 transmission
Makris (2021) (48)	COVID and social distancing with a heterogenous population	Modelling	Limitation of social contacts Lockdown		COVID-19 related mortality
Marchant (2022) (136)	COVID-19 mitigation measures in primary schools and association with infection and school staff wellbeing: An observational survey linked with routine data in Wales, UK	Cross-sectional	School bubbles	Face coverings Physical distancing	COVID-19 cases
Megarbane (2021) (103)	Is Lockdown Effective in Limiting SARS-CoV-2 Epidemic Progression?-a Cross-Country Comparative Evaluation Using Epidemiokinetic Tools	Modelling	Lockdown		COVID-19 transmission
Mensah (2021) (135)	SARS-CoV-2 infections in children following the full re-opening of schools and the impact of national lockdown: Prospective, national observational cohort surveillance, July-December 2020, England	Longitudinal	Lockdown School closures		COVID-19 cases
Meo (2020) (154)	Impact of lockdown on COVID-19 prevalence and mortality during 2020 pandemic: observational analysis of 27 countries	Ecological	Lockdown		COVID-19 cases COVID-19 related mortality

Reference	Title	Study design	NPI: reduced contacts	NPI: other	Outcomes
Mintram (2022) (105)	CALMS: Modelling the long-term health and economic impact of COVID-19 using agent-based simulation	Modelling	Lockdown		COVID-19 hospitalisation COVID-19 related mortality
Muegge (2023) (155)	National lockdowns in England: The same restrictions for all, but do the impacts on COVID-19 mortality risks vary geographically?	Ecological	Lockdown		COVID-19 related mortality
Munday (2021) (106)	Estimating the impact of reopening schools on the reproduction number of SARS-CoV-2 in England, using weekly contact survey data	Modelling	School closures		COVID-19 transmission
Munday (2021) (123)	Implications of the school-household network structure on SARS-CoV-2 transmission under school reopening strategies in England	Modelling	School closures		COVID-19 transmission
Novakovic (2022) (50)	The CP-ABM approach for modelling COVID-19 infection dynamics and quantifying the effects of non-pharmaceutical interventions	Modelling	Lockdown	Face coverings	COVID-19 cases
Panovska-Griffiths (2020) (108)	Determining the optimal strategy for reopening schools, the impact of test and trace interventions, and the risk of occurrence of a second COVID-19 epidemic wave in the UK: a modelling study	Modelling	School closures		COVID-19 cases COVID-19 related mortality COVID-19 transmission
Panovska-Griffiths	Modelling the impact of reopening schools in the UK in early 2021 in the presence of the alpha variant and with roll-out of vaccination against SARS-CoV-2	Modelling	School closures		COVID-19 cases COVID-19 related mortality

Reference	Title	Study design	NPI: reduced contacts	NPI: other	Outcomes
(2022) (110)					COVID-19 transmission
Post (2021) (111)	How did governmental interventions affect the spread of COVID-19 in European countries?	Modelling	Lockdown		COVID-19 transmission
Rice (2020) (51)	Effect of school closures on mortality from coronavirus disease 2019: old and new predictions	Modelling	Limitation of social contacts School closures	Isolation of cases Isolation of contacts Shielding	COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality
Robles-Zurita (2023) (113)	Reducing the basic reproduction number of COVID-19: a model simulation focused on QALYs, hospitalisation, productivity costs and optimal (soft) lockdown	Modelling	Lockdown		COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality
Sonabend (2021) (52)	Non-pharmaceutical interventions, vaccination, and the SARS-CoV-2 delta variant in England: a mathematical modelling study	Modelling	Hospitality setting closures School closures		COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality COVID-19 transmission
Violato (2021) (118)	Impact of the stringency of lockdown measures on COVID-19: A theoretical model of a pandemic	Modelling	Lockdown		COVID-19 related mortality

Reference	Title	Study design	NPI: reduced contacts	NPI: other	Outcomes
Wang (2020) (119)	A four-compartment model for the COVID-19 infection-implications on infection kinetics, control measures, and lockdown exit strategies	Modelling	Lockdown		COVID-19 cases COVID-19 hospitalisation
Wells (2020) (53)	Disease control across urban-rural gradients	Modelling	Lockdown	Contact tracing	COVID-19 transmission
Whitfield (2023) (120)	Modelling the impact of non-pharmaceutical interventions on workplace transmission of SARS-CoV-2 in the home-delivery sector	Modelling	Cohorting Workplace closure or work from home	Physical distancing Asymptomatic testing Isolation of cases Isolation of contacts	COVID-19 transmission
Woodhouse (2022) (54)	Alternative COVID-19 mitigation measures in school classrooms: analysis using an agent-based model of SARS-CoV-2 transmission	Modelling	School bubbles	Asymptomatic testing	COVID-19 transmission Lost time (school or work)
Ying (2021) (55)	Modelling COVID-19 transmission in supermarkets using an agent-based model	Modelling	Limitation of social contacts	Face coverings Physical distancing	COVID-19 cases
Zhang (2022) (157)	Evaluating the impacts of tiered restrictions introduced in England, during October and December 2020 on COVID-19 cases: A synthetic control study	Ecological	Tiered restrictions		COVID-19 cases
Ziauddeen (2021) (122)	Modelling the impact of lockdown-easing measures on cumulative COVID-19 cases and deaths in England	Modelling	Lockdown		COVID-19 cases COVID-19 related mortality

Measures implemented in the UK to protect the most vulnerable

Nine studies reporting on measures implemented in the UK to protect the most vulnerable (initially termed 'shielding') were identified (Table 4).

'The most vulnerable' refers to people who were defined as clinically extremely vulnerable due to a clinical condition (including, but not limited to, those who had had a solid organ transplant, who had certain types of cancer treatment, who had blood or bone marrow cancer, who had a severe lung condition such as cystic fibrosis or severe asthma, people with rare diseases that significantly increase the risk of infections, people on immunosuppression therapies and adults with Down's syndrome), or based on the clinical judgement that they were at higher risk of severe COVID-19 outcomes. The list of those considered as clinically extremely vulnerable was updated continually throughout the pandemic and, in England, clinically extremely vulnerable people were no longer advised to shield from 1 April 2021 (180).

Of these 9 studies, 6 (67%) were modelling (27, 35, 39, 51, 116, 117) and 3 were longitudinal studies (127, 131, 134). No experimental studies were identified. All studies reported on outcomes related to COVID-19 transmission.

Four out of the 9 studies focused on assessing the effectiveness of shielding (in the other 5, other NPIs were also assessed), of which 2 were longitudinal studies which compared COVID-19 outcomes between individuals who had received a shielding letter and those who did not (127, 134).

The studies identified for this category can be visualised by NPI and study design in the interactive Evidence gap map: effectiveness of non-pharmaceutical interventions to reduce transmission of COVID-19 in the UK. In the 'mosaic' view, each 'tile' corresponds to one study with the outcome in colour. Studies reporting on more than one NPI or more than one outcome are mapped to more than one 'tile'. Click on the arrow next to the NPI category to expand the category you want to explore.

Table 4. List of studies identified on measures implemented in the UK to protect the most vulnerable

Reference	Title	Study design	NPI: to protect the most vulnerable	NPI: other	Outcomes
Bays (2021) (27)	Insights gained from early modelling of COVID-19 to inform the management of outbreaks in UK prisons	Modelling	Shielding	Isolation of cases Cohorting	COVID-19 hospitalisation COVID-19 transmission
Coleman (2022) (131)	Implementation of novel and conventional outbreak control measures in managing COVID-19 outbreaks in a large UK prison	Longitudinal	Shielding	Isolation of cases Isolation of contacts Cohorting	COVID-19 cases
Davies (2020) (35)	Effects of non-pharmaceutical interventions on COVID-19 cases, deaths, and demand for hospital services in the UK: a modelling study	Modelling	Shielding	Physical distancing Isolation of cases Lockdown School closures	COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality COVID-19 transmission
Gosce (2020) (39)	Modelling SARS-COV2 Spread in London: Approaches to Lift the Lockdown	Modelling	Shielding	Asymptomatic testing Lockdown	COVID-19 cases COVID-19 related mortality COVID-19 transmission

Reference	Title	Study design	NPI: to protect the most vulnerable	NPI: other	Outcomes
Jani (2021) (134)	Comparison of COVID-19 outcomes among shielded and non-shielded populations	Longitudinal	Shielding		COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality
Kumari (2021) (127); preprint	Targeted Shielding and Coronavirus Symptoms Among Adults in the UK	Longitudinal	Shielding		COVID-19 cases
Rice (2020) (51)	Effect of school closures on mortality from coronavirus disease 2019: old and new predictions	Modelling	Shielding	Limitation of social contacts School closures Isolation of cases Isolation of contacts	COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality
Smith (2022) (116)	Critical weaknesses in shielding strategies for COVID-19	Modelling	Shielding		COVID-19 cases COVID-19 hospitalisation COVID-19 related mortality
van Bunnik (2021) (117)	Segmentation and shielding of the most vulnerable members of the population as elements of an exit strategy from COVID-19 lockdown	Modelling	Shielding		COVID-19 transmission

Travel and border restrictions implemented in the UK

Five studies reporting on travel restrictions (30, 36, 70, 147, 149) were identified and 7 on border restrictions (60, 61, 72, 78, 79, 164, 166) (Table 5).

Travel restrictions included international (36, 147) or within UK (70) travel restrictions. Border measures identified included testing strategies, self-isolation, test to release, symptom and temperature screening, and provision of public health information. Testing, isolation (also called quarantine) and test to release strategies directly linked to travel were included in this category rather than under 'measures to identify and isolate those who are infectious or may become infectious' as these are different from the measures which targeted everyone in the community to reduce community transmission. In contrast, testing and isolation in the context of travel specifically targeted travellers (and in some cases included quarantine in hotels rather than at home) and aimed not only to reduce transmission but also to avoid introduction of new variants.

Of these 12 studies, 8 (67%) were modelling (30, 36, 60, 61, 70, 72, 78, 79), one was cross-sectional (147), one ecological (149), one mixed-methods (164) and one qualitative (166). No experimental or individual-level observational studies were identified. The qualitative and mixed-method studies reported on behavioural outcomes whilst the other studies all reported on transmission-related outcomes.

Nine out of the 12 studies only reported on the effectiveness of travel and border restrictions (no other NPIs assessed).

The studies identified for this category can be visualised by NPI and study design in the interactive Evidence gap map: effectiveness of non-pharmaceutical interventions to reduce transmission of COVID-19 in the UK. In the 'mosaic' view, each 'tile' corresponds to one study with the outcome in colour. Studies reporting on more than one NPI or more than one outcome are mapped to more than one 'tile'. Click on the arrow next to the NPI category to expand the category you want to explore.

Table 5. List of studies identified on travel and border restrictions implemented in the UK

Reference	Title	Study design	NPI: travel and border	NPI: other	Outcomes
Aggarwal (2021) (147); preprint	An integrated analysis of contact tracing and genomics to assess the efficacy of travel restrictions on SARS-CoV-2 introduction and transmission in England from June to September, 2020	Cross-sectional	Travel restrictions		COVID-19 transmission
Bays (2021) (61)	What effect might border screening have on preventing the importation of COVID-19 compared with other infections? A modelling study	Modelling	Border measures		COVID-19 cases
Bays (2022) (60)	What effect might border screening have on preventing importation of COVID-19 compared with other infections?: considering the additional effect of post-arrival isolation	Modelling	Border measures		COVID-19 cases
Cai (2022) (166)	Learning about COVID-19 across borders: public health information and adherence among international travellers to the UK	Qualitative	Border measures		Behavioural outcomes
Chen (2021) (30); preprint	Scenario analysis of non-pharmaceutical interventions on global COVID-19 transmissions	Modelling	Travel restrictions	Face coverings Limitation of social contacts Lockdown School closures	COVID-19 cases
Clifford (2020) (79)	Effectiveness of interventions targeting air travellers for delaying local outbreaks of SARS-CoV-2	Modelling	Border measures		COVID-19 transmission

Reference	Title	Study design	NPI: travel and border	NPI: other	Outcomes
Clifford (2021) (78)	Strategies to reduce the risk of SARS-CoV-2 importation from international travellers: Modelling estimations for the United Kingdom, July 2020	Modelling	Border measures		COVID-19 transmission
Dong (2022) (36)	Deep recurrent reinforced learning model to compare the efficacy of targeted local versus national measures on the spread of COVID-19 in the UK	Modelling	Travel restrictions	Limitation of social contacts Lockdown School closures	COVID-19 cases COVID-19 related mortality
Gianino (2021) (149)	Evaluation of the Strategies to Control COVID-19 Pandemic in Four European Countries	Ecological	Travel restrictions	Contact tracing Limitation of social contacts School closures Workplace closure or work from home	COVID-19 transmission
Ruget (2021) (70); preprint	Risk of COVID-19 Introduction into the Scottish Hebrides and Strategies for Control	Modelling	Travel restrictions		COVID-19 transmission
Taylor (2020) (72); preprint	The risk of introducing SARS-CoV-2 to the UK via international travel in August 2020	Modelling	Border measures		COVID-19 cases
Zhang (2021) (164)	Public health information on COVID-19 for international travellers: lessons learned from a mixed-method evaluation	Mixed methods	Border measures		Behavioural outcomes

Inequalities

Impact of NPIs on health inequalities was out of scope. As the objective of this work was to map the studies rather than summarise them narratively, it was not possible to draw out relevant evidence related to both effectiveness of NPIs and health inequalities.

Limitations

Our mapping review followed streamlined methodologies: 85% of the records included on title and abstract were screened by only one reviewer (as per our usual rapid review methodology, see Annexe A), and primary evidence published in 2020 was identified using existing systematic reviews rather than through database searches. Therefore, relevant studies may have been missed. In addition, coding and data extraction was done by one reviewer and checked by another rather than being done independently by 2 reviewers.

Specific search terms relating to NPIs of interest were included in the search strategy; a validated UK geographic search filter was also used in order to limit the evidence retrieved to UK settings (181, 182). However, as with all search strategies, the evidence retrieved is limited by the search terms used so relevant studies may have been missed.

Our mapping review was limited to evidence from the COVID-19 pandemic, we did not include evidence from other infectious diseases.

The review question was broad in terms of exposures and outcomes. In particular, the criteria for exposure ('NPI implemented in the UK') occasionally required subjective judgement in assessing whether it had been implemented in the UK as well as in assigning the intervention described to a specific NPI category, which may have led to inconsistencies. Similarly, the inclusion criteria for studies reporting on behavioural outcomes and on work and education time lost also required subjective judgement, which may have led to inconsistencies.

Quality of the included studies was not assessed, and narrative synthesis of study findings was not conducted as this was a mapping review (future work includes critical appraisal and evidence synthesis). Mapping of the evidence was done in function of NPI, study design and outcomes. Additional potentially relevant analyses, including in function of study period (and therefore variant in circulation or vaccination coverage), settings (schools, household, workplace, and so on) or UK regions was not conducted although corresponding information was extracted for each study (see data extraction tables in the supplementary material).

Conclusions

A total of 151 studies reporting on effectiveness of NPIs implemented in the community to reduce the transmission of COVID-19 in the UK were identified (some studies reported on more than one NPI).

More than half of the studies identified (80 out of 151) reported on measures to identify and isolate those who are infectious or may become infectious, including asymptomatic testing (30 studies), contact tracing (27 studies) and isolation of cases (21 studies). Of the 80 studies, 2 were RCTs (both on test and release strategies) and 7 were longitudinal studies.

Measures to reduce the numbers of contacts were reported in about half of the studies (71 out of 151), especially lockdown (36 studies), followed by school closures (17 studies) and limitation of social contacts (17 studies). There were no experimental studies identified for this category, and only 2 longitudinal and 3 cross-sectional studies.

Nineteen studies reported on measures aimed to reduce infection risk at individual level, especially face coverings (14 studies). There was little evidence identified on physical distancing (7 studies), ventilation (5 studies), hand hygiene (2 studies) or cleaning (1 study). No experimental or longitudinal studies were identified, and there were only 3 cross-sectional studies (all based on self-reported data). The evidence available for this category is therefore likely to be weak, both in terms of study design and potential bias.

There were 12 studies reporting on travel and border restrictions, of which 8 were modelling studies. No experimental or longitudinal studies were identified and there was only one cross-sectional study, suggesting a weak evidence base in terms of study design.

Nine studies were identified on measures to protect the most vulnerable, of which 2 were longitudinal studies with control group that reported on the effectiveness of shielding.

These findings suggest that most of the published research on effectiveness of NPIs implemented in community settings in the UK was focused on measures to identify and isolate those who are infectious or may become infectious (such as asymptomatic testing, contact tracing and isolation of cases) and on measures to reduce the number of contacts (such as lockdown, school closures and limitation of social contacts). Except for face coverings, there is an evidence gap on the effectiveness of measures to reduce infection risk at individual level such as hand and respiratory hygiene, ventilation and cleaning. However, it should be noted that studies that reported on packages of NPIs (without reporting on effectiveness of individual NPIs) and studies that assessed performance of specific protocols or products before implementation as an intervention (for instance, a laboratory study reporting on a cleaning procedure or a study assessing flow rate or air changes per hour when opening a window) were excluded.

The evidence generated on the effectiveness of NPIs implemented in community settings to reduce the transmission of COVID-19 in the UK was primarily based on modelling studies (100 out of 151 studies) and there was a lack of experimental studies (2 out of 151 studies) and individual-level observational studies (22 out of 151 studies). Apart from test and release

strategies for which 2 RCTs were identified, the body of evidence available on effectiveness of NPIs in the UK provides weak evidence in terms of study design, as it is mainly based on modelling studies, ecological studies, mixed-methods studies and qualitative studies. This is a key learning for future pandemic preparedness as there is a need to strengthen evaluation of interventions and build this into the design and implementation of public health interventions and government policies from the start of any future pandemic or other public health emergency.

The 2 RCTs were both funded by DHSC, and both had authors affiliated to UKHSA or PHE as well as NIHR HPRUs. More generally, 9% of all studies had been funded by DHSC, 21% had at least one UKHSA (or PHE) author and 26% had at least one author with an NIHR HPRU affiliation, going up to 24%, 41% and 45%, respectively, without the modelling studies. Whilst these results suggest that DHSC and UKHSA have had a key role in evaluating the interventions implemented during the COVID-19 pandemic, UKHSA is strengthening its capabilities for evaluation of interventions including to support rapid evaluation in the context of emergencies working in partnership with academic partners.

Whilst this body of evidence overall provides weak evidence in terms of study design (study designs at the lower end of the hierarchy of evidence such as cross-sectional studies are at higher risk of bias than studies at the higher end of the hierarchy of evidence such as RCT) and potentially in terms of study quality (although critical appraisal was not performed), the wider challenges of the pandemic should be acknowledged, including the limited resources that were available. It is also worth noting that the traditional evidence hierarchies and corresponding ‘low level of evidence’ and ‘low or very low certainty’ of the GRADE framework were developed to inform clinical practice where RCTs are feasible, and linear causal pathways are more often the norm. Public health research does not always fit easily within this framework, and the evaluation and application of natural experiments warrants further consideration.

The aim of this mapping review was to identify and categorise the evidence available. The next steps are to critically appraise and synthesise the evidence identified on the effectiveness of individual NPIs implemented in community settings to reduce the transmission of COVID-19 in the UK. There is also a need to review and assess the evidence on the economic impact of NPIs as well as their wider impact, including on mental health and health inequalities.

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206. Health and Social Care (Scottish Government). 'Compliance with self-isolation and quarantine measures: literature review' 2021

Annexe A. Methods

This report followed streamlined systematic methods to address the review question "What evidence exists of the effectiveness of the non-pharmaceutical interventions (NPIs) as implemented in the community in the UK to control the COVID-19 pandemic?"

To tackle this broad question, a rapid mapping review was conducted to identify studies that reported on effectiveness of NPIs implemented in the UK. Primary studies (published between 1 January 2020 and 28 February 2023 – search date: 1 March 2023) were identified through 2 main sources:

- relevant systematic reviews (identified via a previous scoping exercise) for studies published up to 31 December 2020
- literature search for studies published from 1 January 2021 onwards

Our rapid mapping review approach followed streamlined systematic methodologies (19). For instance, full text screening and data extraction were performed by one reviewer and checked by another instead of being conducted in duplicate.

This mapping review was conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews checklist (PRISMA-ScR) (183) which is also applicable to mapping reviews (18).

Protocol

A protocol was produced before the literature search began, specifying the review question and the inclusion and exclusion criteria. The protocol is available on request.

Modifications made to the protocol after the review started are reported below, where relevant.

Inclusion and exclusion criteria

Article eligibility criteria are summarised in Table A.1.

Table A.1. Inclusion and exclusion criteria

	Included	Excluded
Population	All population, UK	Non-UK studies
Settings	Community settings	Health and social care settings
Context	COVID-19 pandemic	Other infectious diseases
Intervention / exposure	All types of NPI implemented in the UK, including: • testing • contact tracing • isolation of cases	• Studies assessing performance of specific tests or products (rather than assessing an intervention)

	Included	Excluded
	• isolation of contacts • lockdown • physical distancing • limitation of social contact • limitation of large gathering • cleaning • hand and respiratory hygiene • face covering • school closures • workplace closure and working from home • hospitality setting closure • border restriction • ventilation Studies that reported on the impact of not having the intervention (for instance, impact of delayed contact tracing due to faulty system, or impact of re-opening schools) were considered for inclusion.	• Studies comparing effectiveness of different types of face coverings (rather than assessing effectiveness of wearing face coverings as an intervention) • Personal Protective Equipment (PPE) (gowns, goggles, aprons and so on) and interventions specific to health and social care settings
Outcomes	Any outcomes related to the impact of the intervention on the COVID-19 pandemic, including but not limited to: • COVID-19 transmission or cases • COVID-19 incidence or prevalence • COVID-19 hospitalisation • COVID-19 deaths • compliance, adherence, knowledge and behaviour • socioeconomic impacts	Studies were excluded if their primary outcomes are: • economic outcomes • health outcomes other than those related to COVID-19 outcomes Studies that reported on knowledge and behavioural factors related to COVID-19 but not as impact of an intervention were excluded.
Language	English	
Date of publication	1 January 2020 to February 2023	
Study design	• Experimental and quasi experimental studies • Cohort and case control studies • Outbreak investigations	• Systematic or narrative reviews • Guidelines • Opinion pieces

	Included	Excluded
	• Cross sectional studies • Ecological studies [A] • Modelling studies [B]	
Publication type	Published and preprint	Conference abstracts

[A] International ecological studies which did not provide evidence on effectiveness of NPIs as implemented in the UK were excluded (for instance, cross-countries ecological studies that pooled UK data with data from other countries without reporting effectiveness data specific to the UK were excluded).

[B] Modelling studies that reported on hypothetical cases or populations not directly relevant to the UK were excluded (modelling studies using hypothetical cases or assumptions were included if authors were from the UK).

Sources searched

1. Relevant systematic reviews (identified via a previous scoping exercise) for studies published up to 31 December 2020 – see Annexe C for more details about the scoping searches.
2. Databases used for the literature search: Ovid Medline, Ovid Embase, medRxiv, aRxiv and Research Square preprints (via NIH iSearch Covid Portfolio) and CoronaCentral.
3. Additional sources of evidence: previous work conducted by the COVID-19 rapid evidence service (23), internal lists of studies and publications with UKHSA involvement (including a list of UKHSA study protocols registered with the Research Ethics and Governance Group [REGG] and a list of relevant non-REGG protocols) and the UKHSA research portal.

Modifications made to the protocol

WHO COVID-19 Research Database was listed as a source in the protocol but due to the high number of hits retrieved by a trial search of this database, of which a large proportion were not specific to the UK, it was decided to not use the WHO COVID-19 Research Database and instead search CoronaCentral (which uses machine learning to identify and categorise published papers and preprints on SARS-CoV-2); searching a limited number of databases is in line with rapid review methodologies (19, 184)

Search strategy

Databases searches were conducted for papers published between 1 January 2021 and 28 February 2023 (search date: 1 March 2023).

Search terms covered key aspects of the review question. The geographical search filter developed by the National Institute for Health and Care Excellence (NICE) was used to limit the search results to UK studies (181, 182).

The search strategy was drafted by an Information Scientist and peer-reviewed by a second Information Scientist. The search strategy for Ovid Medline is presented in Annexe B.

Screening

Screening of the list of included studies of relevant systematic reviews was done on title and abstract by one reviewer. Full-text screening was done by one reviewer and checked by a second.

Title and abstract screening of database search results was done by 4 reviewers using EPPI-Reviewer web version (20): 5% of the eligible studies were first screened independently by the 4 reviewers and disagreements were resolved by discussions. A further 10% were screened independently in duplicate (5% by 2 reviewers and 5% by the other 2 reviewers) and disagreements were resolved by discussion between the 4 reviewers. The remaining 85% were screened individually by one of 4 reviewers, with discussion with another reviewer in areas of uncertainty.

Full text screening was done by one reviewer and checked by a second using EPPI-Reviewer. Disagreements were resolved by discussion with a third reviewer. A list of excluded studies with reasons for exclusion is presented in supplementary material.

The PRISMA diagram showing the flow of citations is provided in Figure A.1.

Modifications made to the protocol

It was anticipated that title and abstract screening would be done by 2 reviewers, with 10% duplicate; however, due to the high number of records retrieved by the literature search, 4 reviewers were involved in title and abstract screening and additional screening was done in duplicate to ensure consistency between reviewers

Data extraction

The codes used for the mapping (study design, NPI and outcomes) were extracted in EPPI-Reviewer during full-text screening by one reviewer (checked by a second reviewer when completing the data extraction). See more details about the coding below under ‘synthesis’.

Summary information for each study was then extracted and reported in tabular form in a word document by one reviewer and checked by a second. Information included study design, setting, study period, intervention (and control if applicable), outcomes and study funding. The data extraction template was piloted by the 4 reviewers who worked on the data extraction, with input from a senior reviewer and 2 topic advisors.

Modifications made to the protocol

The following modifications were made mainly due to the high number of records identified:

- the protocol reported that the key findings of the studies would be extracted, although it was then agreed between reviewers and topic advisors that this would not be done due to high volume of records identified
- coding at the full-text screening stage was not part of the initial protocol, this was decided once title and abstract screening had been completed

Risk of bias assessment

For this mapping review, it was agreed when drafting the protocol that critical appraisal would not be performed as the main aim of this work was to identify and categorise the evidence identified.

Synthesis

Narrative synthesis of the evidence was not performed, although a description of the evidence identified (including number of studies and breakdown by study design and NPI) was provided.

Visual synthesis was performed by generating an interactive evidence gap map with EPPI-Mapper (21), using the coding extracted at full-text screening to represent the evidence identified on NPI by function of study design, with a third dimension (mosaic tiles) added to represent the outcomes.

There were 2 levels of NPI coding (parent and child codes):

- measures to reduce infection risk at individual level
  - face covering use
  - physical distancing (that is, keeping a distance of 1 or 2 metres between people, sometimes called ‘social distancing’)
  - hand and respiratory hygiene (but mapped as ‘hand hygiene’ only as no evidence on respiratory hygiene was identified)
  - cleaning (such as cleaning of surfaces)
  - ventilation

- measures to identify and isolate those who are infectious or may become infectious
  - contact tracing
  - asymptomatic testing

  - symptomatic testing
  - isolation of cases
  - isolation of contacts
  - test and release strategies

- measures to reduce the numbers of contacts
  - lockdown
  - tiered restrictions
  - hospitality setting closures
  - workplace closure or working from home
  - school closures
  - school bubbles
  - cohorting
  - limitation of social contacts
  - restrictions of large gatherings

- measures to protect the most vulnerable
  - shielding measures

- travel and border restrictions
  - border measures (such as self-isolation or testing on arrival)
  - travel restrictions (such as travel corridors)

An additional code ('multiple NPI') was used during the data extraction on EPPI-Reviewer in order to assess how many studies reported on effectiveness of more than one NPI. However, this code was not used in the final mapping to avoid confusion (studies that reported on the effectiveness of a package of NPIs without reporting on individual NPIs were excluded).

In terms of outcomes, the following codes were used:

- COVID-19 transmission (such as R numbers and secondary infection rates, but proxy data for transmission risk such as whether an outbreak happened was also included)
- COVID-19 cases (such as number of positive tests)
- COVID-19 hospitalisations (such as number of hospitalisations or Intensive Care Unit admissions)
- COVID-19 mortality (such as number of COVID-19 related deaths reported by the Office for National Statistics)

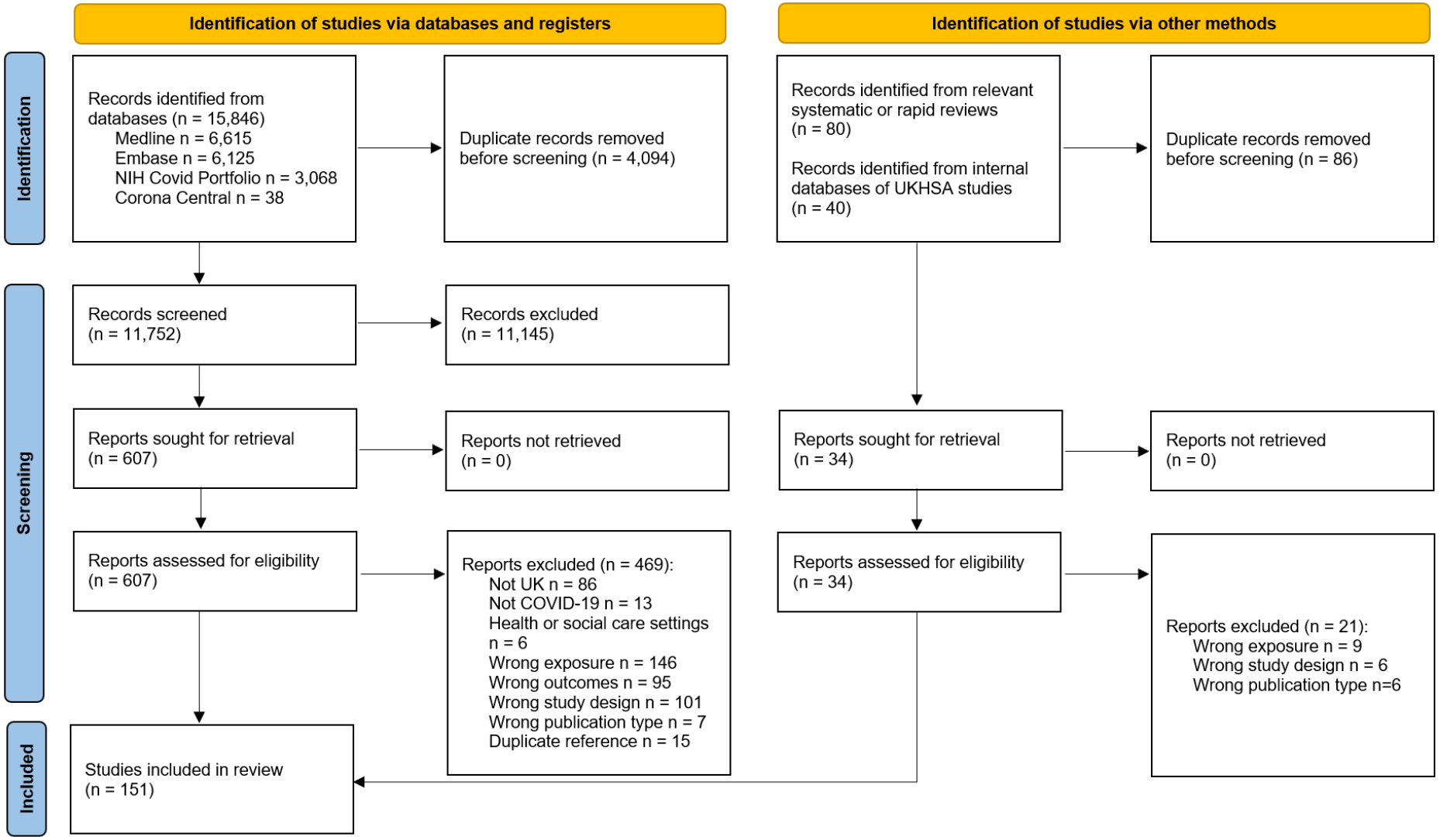
- behavioural outcomes (such as compliance, adherence, perceptions and attitudes)
- lost time (school or work) as a measure of how the different NPI implemented impacted school or work attendance (outcome initially called ‘socio-economic outcomes’ but was then re-named to avoid confusion as economic studies and studies reporting on health inequalities were out of scope)

In terms of study designs, the following codes were used:

- randomised controlled trials
- non randomised controlled trials (no study identified)
- longitudinal studies
- cross-sectional studies
- ecological studies
- modelling studies
- mixed-methods studies
- qualitative studies

Note that the NPI and outcomes were listed in the initial protocol but that some modifications were made for the purpose of the mapping. For instance, ‘isolation’ was split into ‘isolation of cases’ and ‘isolation of contacts’ and ‘limitations of social events’ was split into ‘limitation of social contacts’ and ‘restriction of large gatherings’. However, no changes to the types of outcomes or NPI included were made after the protocol was drafted (only changes to the coding itself).

Figure A.1. PRISMA diagram



Text equivalent of PRISMA diagram showing the flow of studies through this review, including 151 studies in a search up to 28 February 2023

From identification of studies via databases and registers, n=15,846 records were identified from databases:

- Medline n=6,615
- Embase n=6,125
- NIH Covid Portfolio n=3,068
- Corona Central n=38

From these, 4,094 duplicate records were removed before screening.

After removal of duplicates, n=11,752 records were screened on title and abstract, of which n=11,145 were excluded, leaving n=607 papers sought for retrieval.

The 607 papers were assessed for eligibility on full text (n=0 reports not retrieved). Of these, 469 were excluded:

- not UK n=86
- not COVID-19 n=13
- health and social care settings n=6
- wrong exposure n=146
- wrong outcomes n=95
- wrong study design n=101
- wrong publication type n=7
- duplicate references n=15

One hundred and twenty additional records were identified through additional sources:

- records identified from relevant systematic or rapid reviews: n=80
- records identified from internal databases of UKHSA studies: n=40

From these, 86 duplicate records were removed before screening.

After removal of duplicates, n=34 records were sought for retrieval.

The 34 papers were assessed for eligibility on full text (n=0 reports not retrieved). Of these, 21 were excluded:

- wrong exposure n=9
- wrong study design n=6
- wrong publication type n=6

In total, 151 studies were included.

Annexe B. Search strategy for Ovid MEDLINE

Search strategy for Ovid Medline ALL (1946 to 28 February 2023):

1. exp SARS-CoV-2/ (149010)
2. exp COVID-19/ (211700)
3. (corona* adj1 (virus* or viral*)).tw,kw,kf. (6005)
4. (CoV not (Coefficien* or "co-efficien*" or covalent* or Covington* or covariant* or covarianc* or "cut-off value*" or "cutoff value*" or "cut-off volume*" or "cutoff volume*" or "combined optimi?ation value*" or "central vessel trunk*" or CoVR or CoVS)).tw,kw,kf. (114761)
5. (coronavirus* or 2019nCoV* or 19nCoV* or "2019 novel*" or Ncov* or "n-cov" or "SARS-CoV-2*" or "SARSCoV-2*" or SARSCoV2* or "SARS-CoV2*" or "severe acute respiratory syndrome*" or COVID*2).tw,kw,kf. (348974)
6. exp COVID-19 Vaccines/ (19725)
7. exp COVID-19 Testing/ (10582)
8. or/1-7 (356560)
9. Contact Tracing/ (6149)
10. ((contact or source or infection or patient or case) adj2 (screen* or notificat* or trac* or investig*)).tw,kf. (84268)
11. (NPI* or ((non-pharm* or nonpharm*) adj intervention*) or "public health measure*" or (prevent* adj2 measure*)).tw,kf. (64487)
12. 9 or 10 or 11 (151494)
13. Quarantine/ (6157)
14. Social Isolation/ (16021)
15. (quarantin* or isolat*).ti,kf. or (quarantin* or isolat*).ab. /freq=2 (660072)
16. 13 or 14 or 15 (674277)
17. exp *COVID-19 Testing/ (2922)
18. Point-of-Care Testing/ or Self-Testing/ (4286)
19. Reagent Kits, Diagnostic/ (17583)
20. ("lateral flow" or LFT or LFA or LFD or LFIA).tw,kf. (14022)
21. ((COVID or Corona*) adj2 test*).tw,kf. (6976)
22. 17 or 18 or 19 or 20 or 21 (44206)

23. (lockdown* or lock-down*).ti,kf. or (lockdown* or lock-down*).ab. /freq=2 (11563)
24. ((stay adj2 home) or shielding).tw,kf. (18972)
25. Physical Distancing/ (2290)
26. ((physical* or social*) adj distan*).tw,kf. (14129)
27. ((social* or societal* or gathering* or meeting* or event*) adj3 (restrict* or prohibit* or limit* or ban* or cancel*)).tw,kf. (13637)
28. (tier* adj2 restric*).tw,kf. (26)
29. 23 or 24 or 25 or 26 or 27 or 28 (55787)
30. exp Disinfectants/ or Disinfection/ (87461)
31. ((environment* or surface* or home* or house* or workplace*) adj3 disinfect*).tw,kf. (2948)
32. ((environment* or surface* or home* or house* or workplace*) adj3 clean*).tw,kf. (7988)
33. ((environment* or surface* or home* or house* or workplace*) adj3 decontaminat*).tw,kf. (1294)
34. deep clean*.tw,kf. (69)
35. 30 or 31 or 32 or 33 or 34 (97245)
36. exp Hand Hygiene/ (8077)
37. (hand wash* or handwash*).tw,kf. (6450)
38. hand saniti*.tw,kf. (961)
39. ((hand or personal) adj hygiene).tw,kf. (8768)
40. 36 or 37 or 38 or 39 (17443)
41. (facemask* or mask*).tw,kf. (100303)
42. Masks/ (7178)
43. (face adj2 (cover* or protect*)).tw,kf. (1081)
44. (mouth adj2 (cover* or protect*)).tw,kf. (361)
45. (nose adj2 (cover* or protect*)).tw,kf. (152)
46. (respirator or respirators).tw,kf. (6906)
47. 41 or 42 or 43 or 44 or 45 or 46 (108178)
48. ((universit* or college* or school*) adj3 clos*).tw,kf. (3072)
49. ((office* or work*) adj3 clos*).tw,kf. (5675)
50. (home* adj3 work*).tw,kf. (10428)
51. ((hospitalit* or restaurant* or cafe* or venue* or shop* or retail* or hotel* or leisure or gym* or cinema* or theatre* or theater*) adj3 clos*).tw,kf. (486)

52. 48 or 49 or 50 or 51 (19309)
53. border health.tw,kf. (266)
54. (Travel* adj5 (ban* or restrict*)).tw,kf. (1827)
55. (Border* adj5 (control* or restrict*)).tw,kf. (2125)
56. ((entrance or Entry) adj5 restrict*).tw,kf. (1034)
57. (Movement* adj5 restrict*).tw,kf. (5642)
58. 53 or 54 or 55 or 56 or 57 (10676)
59. ((ventilation or ventilated) and (transmission* or distanc* or dispers* or aerosol* or airborne or air qualit* or indoor air)).tw,kf. (8989)
60. Ventilation/ (6327)
61. (air flow* or airflow* or aerodynamic* or air condition*).tw,kf. (37245)
62. Air Conditioning/ (2867)
63. (air filter* or air purif* or air filtration).tw,kf. (2748)
64. Air Filters/ (586)
65. (air chang* or air exchang*).tw,kf. (1852)
66. (air adj3 (recondition* or re condition*)).tw,kf. (1)
67. (air adj3 replac*).tw,kf. (400)
68. (indoor air adj3 qualit*).tw,kf. (2918)
69. HVAC.tw,kf. (564)
70. Air Microbiology/ (8274)
71. 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 (62693)
72. 12 or 16 or 22 or 29 or 35 or 40 or 47 or 52 or 58 or 71 (1195929)
73. 8 and 72 (63507)
74. exp United Kingdom/ (388488)
75. (national health service* or nhs*).ti,ab,in. (262664)
76. (english not ((published or publication* or translat* or written or language* or speak* or literature or citation*) adj5 english)).ti,ab. (48148)
77. (gb or "g.b." or britain* or (british* not "british columbia") or uk or "u.k." or united kingdom* or (england* not "new england") or northern ireland* or northern irish* or scotland* or scottish* or ((wales or "south wales") not "new south wales") or welsh*).ti,ab,jw,in. (2404695)
78. (bath or "bath's" or ((birmingham not alabama*) or ("birmingham's" not alabama*) or bradford or "bradford's" or brighton or "brighton's" or bristol or "bristol's" or carlisle* or "carlisle's" or (cambridge not (massachusetts* or boston* or harvard*)) or ("cambridge's"

not (massachusetts* or boston* or harvard*)) or (canterbury not zealand*) or ("canterbury's" not zealand*) or chelmsford or "chelmsford's" or chester or "chester's" or chichester or "chichester's" or coventry or "coventry's" or derby or "derby's" or (durham not (carolina* or nc)) or ("durham's" not (carolina* or nc)) or ely or "ely's" or exeter or "exeter's" or gloucester or "gloucester's" or hereford or "hereford's" or hull or "hull's" or lancaster or "lancaster's" or leeds* or leicester or "leicester's" or (lincoln not nebraska*) or ("lincoln's" not nebraska*) or (liverpool not (new south wales* or nsw)) or ("liverpool's" not (new south wales* or nsw)) or ((london not (ontario* or ont or toronto*)) or ("london's" not (ontario* or ont or toronto*)) or manchester or "manchester's" or (newcastle not (new south wales* or nsw)) or ("newcastle's" not (new south wales* or nsw)) or norwich or "norwich's" or nottingham or "nottingham's" or oxford or "oxford's" or peterborough or "peterborough's" or plymouth or "plymouth's" or portsmouth or "portsmouth's" or preston or "preston's" or ripon or "ripon's" or salford or "salford's" or salisbury or "salisbury's" or sheffield or "sheffield's" or southampton or "southampton's" or st albans or stoke or "stoke's" or sunderland or "sunderland's" or truro or "truro's" or wakefield or "wakefield's" or wells or westminster or "westminster's" or winchester or "winchester's" or wolverhampton or "wolverhampton's" or

79. (worcester not (massachusetts* or boston* or harvard*)) or ("worcester's" not (massachusetts* or boston* or harvard*)) or (york not ("new york*" or ny or ontario* or ont or toronto*)) or ("york's" not ("new york*" or ny or ontario* or ont or toronto*))))).ti,ab,in. (1706641)
80. (bangor or "bangor's" or cardiff or "cardiff's" or newport or "newport's" or st asaph or "st asaph's" or st davids or swansea or "swansea's").ti,ab,in. (68546)
81. (aberdeen or "aberdeen's" or dundee or "dundee's" or edinburgh or "edinburgh's" or glasgow or "glasgow's" or inverness or (perth not australia*) or ("perth's" not australia*) or stirling or "stirling's").ti,ab,in. (251449)
82. (armagh or "armagh's" or belfast or "belfast's" or lisburn or "lisburn's" or londonderry or "londonderry's" or derry or "derry's" or newry or "newry's").ti,ab,in. (32893)
83. or/74-81 (3018015)
84. (exp africa/ or exp americas/ or exp antarctic regions/ or exp arctic regions/ or exp asia/ or exp australia/ or exp oceania/) not (exp United Kingdom/ or europe/) (3293714)
85. 82 not 83 (2857491)
86. 73 and 84 (8515)
87. limit 85 to yr="2021 -Current" (6488)
88. limit 85 to dt=20210101-20230301 (6162)
89. 86 or 87 (6630)
90. exp animals/ not humans.sh. (5098481)
91. 88 not 89 (6615)

Annexe C. Scoping searches

A scoping exercise was performed before the review was undertaken as part of best practice in order to identify relevant review-level evidence on NPIs and COVID-19 to inform next steps and reduce duplication of work.

Methods

We used previous recent work conducted on similar topics by Knowledge and Library Services (KLS) to identify relevant reviews on NPIs, border control, contact tracing and quarantine. These scoping searches had been conducted between 30 August 2022 and 31 January 2023 by Information Scientists, using the sources Ovid Medline, Ovid Embase, i.LOVE (Epistemonikos) and Google.

The results were screened on title and abstract for relevance by an Information Scientist. Potentially relevant reviews were then tabulated in an Excel spreadsheet and screened on full-text by a reviewer.

Results

Twenty-five relevant systematic and rapid reviews were identified through the scoping searches (12, 13, 15, 185 to 206). Reviews conducted in the early stage of the pandemic (with search dates before June 2020) were excluded.

Due to the high number of relevant systematic or rapid reviews identified on the effectiveness of NPIs to reduce COVID-19 transmission (some reviews focused on a single NPI, other on a range of NPIs) it was agreed to use these reviews as a source of evidence for primary studies published up to 31 December 2020. We chose to be conservative with the cut-off date to reduce the risk of missing potentially relevant primary studies (a few reviews had conducted their searches in 2022 or 2023, but most of the reviews had conducted their searches in early 2021).

The bibliographies of these 25 reviews were screened on title and abstract by one reviewer. Potentially relevant primary studies were tabulated in an Excel spreadsheet and then screened on full-text by a second reviewer. Studies meeting the inclusion criteria were then added to EPPI-Reviewer for the data extraction stage and mapping.

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