COVID-19 Testing and Diagnosis in Children Under Six Years of Age:

A Systematic Review

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Abstract

Introduction: Severe acute respiratory syndrome was first detected in 2003 and escalated in 2019 with COVID-19 causing a worldwide pandemic. This new virus presented challenges in diagnosis, especially in those under 6 years of age. While often classified as a mild disease in children, COVID-19 still presents significant health risks in the young, especially for children under 1 year of age and those with pre-existing comorbidities. Because of this, clinical guidelines and protocols addressing COVID-19 testing in preschool-aged children became necessary to direct evidence-based practice.

Aim: The aim of this systematic review was to explore COVID-19 testing and diagnosis in children under 6 years of age from international peer-reviewed published manuscripts to facilitate a wider and more thorough understanding of this practice from a diverse sample of parents, children, and health care providers to inform and direct practice within Aotearoa/New Zealand.

Methods: A systematic review was undertaken based on guidelines by Siddaway et al. (2019). Extant empirical research published in peer-reviewed journals from 2020–2024 on COVID-19 testing in children under 6 years of age was identified from Scopus, CINAHL, MEDLINE via PubMed, and PsycInfo via Ovid databases. Data were analysed using deductive thematic analysis.

Findings: Fourteen studies involving over 5,000 participants were included. Deductive content analysis identified seven key areas: 1. Symptomology, 2. Diagnostic tests, 4. Efficacy and acceptability of testing, 4. Viral loads, 5. Vulnerability/Risk factors, 6. Health outcomes, and 7. Recommendations.

Conclusion: While common symptoms such as fever and cough are prevalent in children under 6 years of age infected with COVID-19, symptomology alone is not a foolproof diagnostic tool. Additional diagnostic testing, such as nasopharyngeal swabs and polymerase chain reaction testing, is complementary to diagnosis. However, an understanding of the risk factors for contracting COVID-19, as well as the vulnerability and health outcomes of children with COVID-19, is important to consider.

Implications for practice: Common symptomology for children under 6 years of age includes fever and cough; however, these symptoms are also common for other viruses. A history of exposure to COVID-19 is the most frequent positive predictive factor for infection. An assessment of the child before any decisions on diagnostic testing is useful.

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Signed:

Name: Kirsty Ure

Date: 04/04/2024

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Glossary and Abbreviations

AAP	American Academy of Pediatrics
Anosmia	Loss of smell
ANS	Anterior nasal swab
AUT	Auckland University of Technology
CCW	Childcare worker
CT	Cycle threshold – number of testing cycles run in a laboratory before the virus was detected
DCC	Daycare centre
Dyspnoea	Difficulty breathing
ECE	Early childcare centre
ED	Emergency department in a hospital
H1N1	Type of influenza virus, also called swine flu
ICU	Intensive care unit
JBI	Joanna Briggs Institute
LR	Likelihood ratio
Malaise	Weakness or discomfort, feeling ill
MIQ	Managed isolation and quarantine system set up by the New Zealand Government in response to the COVID-19 pandemic
Myalgia	Muscle aches
NLR	Negative likelihood ratio
NPS	Nasopharyngeal swab
NZ	Aoteroara/New Zealand
Odynophagia	Painful swallowing
ORP	Oropharyngeal swab
OSS	Oral saliva swab
PCR/RT PCR	Reverse transcription polymerase chain reaction-diagnostic test performed in a laboratory that can take between 2 hours and 5 days to process
PLR	Positive likelihood ratio
RAT	Rapid antigen test – A small diagnostic test performed in any setting that typically takes 15 minutes to perform
RCH	Royal Children's Hospital, Melbourne
RSV	Respiratory syncytial virus
SARS	Severe acute respiratory syndrome. Caused by the SARS associated coronavirus
SARS-CoV-2	The coronavirus that causes COVID-19. For ease of reading, in this research, the term COVID-19 is used to describe both the virus and the resulting illness
SCH	Starship Child Health

Definition of COVID-19 severity as defined by Totan et al. (2021)

Asymptomatic infection: A positive test for COVID-19 but no clinical symptoms.

Mild infection: A positive COVID-19 test and some symptoms such as fever, fatigue, myalgia, cough, sore throat, nasal congestion, and runny nose. Not requiring additional clinical support.

Moderate infection: Positive for COVID-19 on testing as well as symptoms such as fever, cough, nasal congestion, sore throat, fatigue, headache and with abnormal radiography or blood tests. May require further clinical support.

Severe infection: Moderate clinical features, lowered oxygen saturation, and any other clinical features suggestive of injuries to vital organs.

Critical infection: Respiratory arrest, organ failure, intensive care unit dependent.

Introduction

Severe acute respiratory syndrome (SARS) was first detected in Asia in 2003 (Centers for Disease Control and Prevention [CDC], 2005). The syndrome was caused by the novel coronavirus, which causes fever and respiratory illness, often including pneumonia (CDC, 2005). At the time, there were no laboratory tests that could specifically be used for diagnosis, and it was noted that a diagnosis of SARS should be considered only when a known contact with SARS had occurred (CDC, 2005). The paediatric population appeared to be less likely to experience SARS, and when a child contracted the virus, it was often reported to be a milder illness (CDC, 2005). Children could be diagnosed with SARS only if there was spread amongst adults at the time, and other pathogens, such as respiratory syncytial virus (RSV) or influenza, needed to be considered first (CDC, 2005). In 2009, a novel influenza virus, influenza A, subtype H1N1 (H1N1), caused a pandemic (CDC, 2005). Worldwide, 80% of deaths from H1N1 were people aged under 65 years, which differed from the usual pattern for influenza (CDC, 2005). Progress has since been made, especially on vaccines and diagnostic laboratory tests such as polymerase chain reaction (PCR) tests and the rapid antigen test (RAT) for SARS and H1N1 (CDC, 2019). A new respiratory pandemic hit the world in 2019, originating in Wuhan, China, in the form of SARS-CoV-2 (now known as COVID-19). Children initially appeared to experience milder signs and symptoms and were often less likely to be tested (CDC, 2005). Much has been learnt from the earlier SARS outbreaks, but COVID-19 presented new challenges, requiring further research and rapid adaptation of practice (Rogers et al., 2020). Currently, research and clinical guidelines for the diagnosis of COVID-19 appear to be unclear, especially for those under 6 years, resulting in confusion among parents and whānau (Kaufman et al., 2023).

Sorg et al. (2022) reported that children and adolescents often follow a mild disease course and low disease-associated morbidity and mortality compared to adults. However, the definitive risk of severe outcomes remains difficult to assess as this requires accurate case numbers, up-to-date knowledge of the population, and the number of cumulative and recent COVID-19 infections (Sorg et al., 2022). Estimations of current COVID-19 rates in children are often incorrect due to undetected COVID-19 infections; therefore, a lack of PCR-confirmed cases was reported to state-based reporting systems (Sorg et al., 2022). Overestimations of COVID-19 infections in children can also be attributed to PCR tests undertaken when a child is hospitalised for another reason or with a co-infection, further skewing the data (Sorg et al., 2022). In Germany, approximately 13.7 million people were aged under 18 in December 2020, and 10.8% of this population had a positive seroprevalence for COVID-19 (Sorg et al., 2022). Hospitalisation rates for COVID-19 treatment were lowest in the 5–11 year age group, and intensive care treatment was highest in children aged 12–17 years compared to other age groups under 18 years (Sorg et al., 2022). Sorg et al. (2022) found that when children with comorbidities were removed for analysis, the estimated risk of hospitalisation due to COVID-19 was 5.19 per 10,000 in the under 18 years age group, and the risk of intensive care unit (ICU) admission due to COVID-

19 was 0.90 per 10,000 children. Comorbidity is a significant risk factor for COVID-19-related hospitalisation and ICU admissions (Shane et al., 2020). For children without comorbidities, the case fatality was 0.03 per 10,000, and no deaths were reported in children older than 5 years of age in Germany (Sorg et al., 2022).

In March 2021, children aged 0–4 years comprised only 2.1% of COVID-19 cases in the USA (Case & Son, 2021). Only 1–5% of these paediatric cases qualified as a severe illness, compared to adults, where 10–20% were classified as severe (Case & Son, 2021). Internationally, children comprised 2% of confirmed COVID-19 cases in the early stages of the pandemic (Nikolopoulou & Maltezou, 2022). As the pandemic progressed, this increased in the USA to 7.4% of preschool children aged 0–4 years; however, it is important to note that estimates vary and suggest that with the inclusion of asymptomatic children, numbers could be as high as 35% (Nikolopoulou & Maltezou, 2022). Of interest, Fougère et al. (2021) reported that the detection rate of COVID-19 significantly differed between age groups, being 3.2% in the 0–6-year-old group and 30.7% in the 6–12-year-old group (p = .004). To date in Aotearoa/New Zealand (NZ), paediatric cases (under 9 years of age) have made up 8.6% of total COVID-19 cases, including 4,197 children aged 0–9 years requiring hospitalisation, 78 children under 9 years requiring ICU, and sadly, 10 children under 9 years of age have died from COVID-19 (Manatū Hauora Ministry of Health, 2024). Currently, the preferred method of COVID-19 diagnostic testing is deoxyribonucleic acid amplification by PCR (Vandenberg et al., 2021). This was one of the first available tests and was developed before the COVID-19 pandemic (Vandenberg et al., 2021). Following this was the development of the RAT to detect an active COVID-19 virus, which is not as sensitive as a PCR test (Rogers et al., 2020). Antibody tests have been suggested as complementary in testing, and immunoassays at the point-of-care are still not universally accepted (Vandenberg et al., 2021). The availability and resources required for each test need to be considered for diagnostic readiness, as the rapid publication of guidelines on COVID-19 testing does not necessarily result in the availability of diagnostic tests and complications arise with limitations in the availability of RAT testing stations/clinics (Rogers et al., 2020). Further, manufacturing problems during the pandemic were evident (Rogers et al., 2020; Vandenberg et al., 2021).

Westbrook et al. (2022) compared rates of COVID-19 in 112 children aged under 4 years old in the USA who reported no symptoms, one isolated symptom, or more than two symptoms. Twenty-one children were asymptomatic, 2 of which tested positive for COVID-19, 16 had one symptom, 5 tested positive for COVID-19, and 75 had two or more symptoms, 11 of which tested positive for COVID-19 (Westbrook et al., 2022). Similarly, Weng et al. (2021) evaluated the diagnostic value of symptoms used by daycare facilities to screen children for COVID-19 in the USA. Symptomatic COVID-19 infections were reported in 38 children and asymptomatic infections occurred in 2 out of 40 COVID-19-positive children aged 0–4 years (Weng et al., 2021). Of interest, 115 children were negative for COVID-19 in this age group using a nasopharyngeal swab (NPS) PCR test (Weng et al., 2021). In another study, Oliver et al. (2021) compared the efficiency and acceptability of saliva samples to oropharyngeal samples. This study included 129 children under 5 years of

age, and 15 children were detected as being COVID-19 positive. Of these 15 positive COVID-19 infections, 8 were detected on oropharyngeal and nasal swabs, 5 on saliva-only swabs, and 2 on both saliva and oropharyngeal nasal swabs (Oliver et al., 2021). In Moraleda et al.'s (2022) study, 516 (44%) out of 1,174 children were under 3 years of age. Of these, 18 children tested positive for COVID-19 (24.7%) by either NPS RAT, oral saliva swab PCR, or NPS PCR. During an observational period of 12 weeks, Engels et al. (2022) collected 5,306 saliva samples, which were analysed by pooled PCR. In addition, 2,896 nasal sample RATs were reported by parents as negative for COVID-19 (Engels et al., 2022). In week 12, only one child had a positive COVID-19 point-of-care antibody test. This child was asymptomatic and had tested negative by saliva and PCR in 21 out of 24 possible tests. At week 12, 6 out of 278 children tested positive for COVID-19 antibodies; 5 had previously tested positive for antibodies at week 1 (Engels et al., 2022).

Forster et al. (2022) investigated the feasibility and efficacy of COVID-19 surveillance testing among young children, childcare workers, and parents in a preschool facility in Würzburg, Germany. This study included 4,755 tests (mid-turbinate nasal PCR and mouth rinsing oral PCR) across four modules, where no positive COVID-19 infections were identified. In module 4, 214 oropharyngeal swabs from 179 symptomatic participants were collected, and COVID-19 was only detected in one childcare worker and one adult household member. In addition, antibody testing did not identify any hidden infections (Forster et al., 2022).

Cohen et al. (2020) conducted a study in Paris, France, comparing PCR tests with blood serology testing to investigate the spread of COVID-19 among children. They discovered that blood serology was positive for COVID-19 in 65 out of 605 (10.7%) children and 87.3% had a confirmed or suspected contact with COVID-19. Only 7 children under 6 years of age were positive for COVID-19 on NPS, and previously symptomatic children were more frequently positive on serology for COVID-19. The results were similar for each age distribution bracket whether the serology results were negative or positive, and not surprisingly, a PCR test was more likely positive for COVID-19 on a child with positive blood serology for COVID-19 (12.3% vs 0.6%, $p < .001$) (Cohen et al., 2020).

Due to the mild or asymptomatic forms of COVID-19 in children, less testing is globally reported in children (Fisman et al., 2021). In addition, the unappealing thought of an NPS may make it less likely for a child to be tested for COVID-19 (Fisman et al., 2021). From September to October 2020, the rate of COVID-19 paediatric cases in the USA and Europe was higher than at the start of the pandemic (Borrelli et al., 2021). This may be due to underestimating or low testing rates in mildly symptomatic children (Borrelli et al., 2021). Australia had a high testing rate but still a low number of confirmed paediatric cases (Borrelli et al., 2021). Borrelli et al. (2021) found a higher risk of disease severity in adolescents, neonates, and preschool children, and reported symptomology as similar to other studies, including respiratory symptoms, gastrointestinal symptoms, headaches, dizziness, myalgia, fevers, fatigue, and skin rash (Borrelli et al., 2021).

Chiwandire et al. (2023) reported that the highest COVID-19 testing rate for children aged under 18 years in South Africa was in infants; however, testing in adults was still higher overall. The testing cases and hospital admission rates among all age groups in the second and third waves increased successively, except for infants, which was lower in the second wave than the first. In the fourth wave, the number of COVID-19 cases was higher amongst those aged under 1 year. Overall, between 2020 and 2022, in under 1-year olds, COVID-19 testing was conducted on 2.2% of the population and the cumulative percentage who tested positive was 11.3%. In the 1–4-year-old age group, COVID-19 testing was conducted on 2.1% of the population, and the cumulative percentage who tested positive for COVID-19 was 8.6% via either RAT or NPS PCR tests (Chiwandire et al., 2023).

In NZ, the proportion of children tested for COVID-19 was low in early 2020 (Chhibber et al., 2020), and to date, the NZ Government lists COVID-19 tests under 9-year-olds at a rate of 872.7 per 1,000 people, where all other age groups are at least over 1,000 per 1,000 people (Manatū Hauora Ministry of Health, 2024). Chhibber et al. (2020) found that 733 out of 22,333 COVID tests were collected in children under 5 years of age, and subsequent positive rates for this age group were even lower (0.14%). Respiratory illness was a commonly reported complaint, and parents were reluctant to get their children tested as they perceived it was more complicated to test a child, as well as a general perception that children would experience lower impacts from COVID-19 (Chhibber et al., 2020; Manatū Hauora Ministry of Health, 2020).

While COVID-19 in children has often been classified as mild, it is still not without risk (Kitano et al., 2021). In a systematic meta-analysis looking at the paediatric COVID-19 impact on countries by income, total worldwide paediatric deaths from COVID-19 were 3,788, and there were 3,118 ICU admissions for children from published literature from 138 countries. In a specific breakdown by age from this literature, authors stated a rate of 10.03 deaths and 16.84 ICU admissions per 1,000,000 in under 1-year olds, and 1.64 deaths and 1.40 ICU admissions per 1,000,000 children in 1–4-year olds (Kitano et al., 2021). Russell and Kvalsvig (2021) also agreed that COVID-19 should not be underestimated in children. Estimates of up to 20% of people who have tested positive for COVID-19 experience symptoms lasting 5 weeks or more, including children (Manatū Hauora Ministry of Health, 2021). Çelik et al. (2021) reported that although the rate of severe illness was lower in children, it was not without risk, especially for children with comorbidities. Çelik et al. (2021) stated that two patients required ICU admissions, and one of these was a 5-month-old baby with a history of prematurity who sadly died. While children may commonly experience a milder form than adults and the elderly, this often results in the failure of COVID-19 testing and subsequent reporting (Russell & Kvalsvig, 2021). Even if a very low percentage of children with COVID-19 require hospitalisation, this adds to an already stretched hospital system, where paediatric ICU beds are often at a critical occupancy level (Russell & Kvalsvig, 2021). In addition, the distribution of specialist child health care delivery and access to care is not equitable across NZ regarding geography, ethnicity, or socioeconomic factors, as seen in a COVID-19 vaccination rollout study by Whitehead et al. (2022). Access to COVID-19 vaccinations across NZ was

inequitable, as Māori and Pasifika, elderly, and rural people had poorer access to these vaccinations (Whitehead et al., 2022). Children from lower socioeconomic families and Māori or Pacifica children already had higher comorbidity levels than their European counterparts (Manatū Hauora Ministry of Health, 2020). The impact of a higher death rate and higher ICU admission rate may be felt greater in countries with a low to middle income (developing countries) rather than those with a higher income (developed countries) (Kitano et al., 2021). COVID-19 has a higher impact on children in terms of comorbidities, and this means children who already have risk factors (chronic illnesses) could be disadvantaged further (Russell & Kvalsvig, 2021). Under 5-year-olds were the last group to be offered COVID-19 vaccination in NZ, and even then, it was to those with comorbidities (Starship Child Health [SCH], 2023). Despite a higher hospitalisation rate among children aged under 4 years during Omicron, children under 6 years of age were still not eligible for vaccination in many countries (Marks et al., 2022). This may be due to younger children being perceived as having a lower risk of severe COVID-19 complications (Russell & Kvalsvig, 2021). However, globally, under 4-year-olds have had high rates of COVID-19 in the Omicron wave, including higher hospitalisation rates, with a higher mortality and ICU admission rate in under 1-year-olds (Davison, 2023; Kitano et al., 2021; Marks et al., 2022). There appears to be an echo of a lag in COVID-19 testing policy for under 6-year-olds globally, with only limited data available on the ongoing short and long-term effects of COVID-19 in children, especially considering the wider social determinants of health. A few children may feel long-term health effects, but non-direct health impacts may be felt by many children, including migrant and marginalised populations (Franco et al., 2022).

Globally, the pandemic and public health response (including lockdowns) to COVID-19 occurred rapidly (Rogers et al., 2020; Vandenberg et al., 2021). It is evident in the literature that best practice clinical guidelines for COVID-19 testing were at risk of not remaining relevant as new data emerged, and clinical guidelines needed to be developed quickly and reviewed regularly with relevance to children (Q. Zhou et al., 2022). An example from my practice comes from working at a RAT collection centre in Christchurch, NZ, in 2022. A child's mother stated that her 2-year-old daughter had to have a negative RAT every day she attended preschool, as mandated by the preschool. This meant the mother had been buying RATs at her own expense and forcing her daughter to have this unpleasant intervention daily. Another preschool required a child to spit into a RAT solution rather than take a nasal swab, with no evidence-based research corroborating this diagnostic test. Informal discussions with colleagues in child health and managed isolation and quarantine (MIQ) facilities around the policy for testing under 6-year-olds revealed much personal experience but no consistency in guidelines or evidence-based practice. Parents were unsure how to test their neonate, infant or younger child, and few options were available. These feelings were echoed by parents in Australia, who found it hard to navigate COVID-19 testing for their children (Kaufman et al., 2023). Having ambiguous or adult-focused clinical guidelines can be confusing for healthcare professionals. Exploring and evaluating the best practice on accuracy, efficacy, and acceptability of COVID-19 testing in pre-schoolers, infants, and neonates is essential within NZ to inform practice, theory, research, education, and policy development.

The COVID-19 pandemic has made paediatric diagnoses, care delivery, referrals and engagement with children and families difficult due to rapid clinical practice changes, isolation precautions, and COVID-19 screening processes (Fatemi & Coffin, 2021). The numerous challenges the COVID-19 pandemic has brought to the healthcare workforce, including fiscal resources, staff stress, fear, workforce shortage, illness, and a rapidly changing and increasing workload, added to COVID-19 diagnostic errors in children (Fatemi & Coffin, 2021; Russell & Kvalsvig, 2021).

Many clinicians understand the anatomical, cognitive, emotional and psychosocial differences between children and adults that require specific, age-appropriate, child-friendly interventions (Manatū Hauora Ministry of Health, 2020). However, most current protocols and information focus on the adult population; therefore, more work is required concerning child health. Adequate guidance for health professionals is vital to direct practice and must be developed clearly and transparently to guide robust evidence-based practice (Q. Zhou et al., 2022). Healthcare professionals, researchers, and organisations must understand that children are not small adults. Because of this there is a present need to focus on operationalising specific contemporary evidence-based practice guidelines and protocols for COVID-19 testing/screening in younger children. This in turn will direct future practice, knowledge, research, and the generation of developmentally age-specific COVID-19 guidelines to ensure best healthcare delivery and outcomes for children (Q. Zhou et al., 2022). Early and accurate diagnosis of COVID-19 in children can also aid in vulnerable and minority populations having access to adequate resources and healthcare (Manatū Hauora Ministry of Health, 2020). With the predominance of protocols being adult-based, it is not clear if the existing protocols are adequate to protect younger preschool children best; therefore, this project seeks to ascertain: What is best practice in testing and diagnosing COVID-19 in children under 6 years of age and what are the implications for practice in NZ?

Methods

Aim

The aim of this systematic review was to explore COVID-19 testing (best practice, efficacy, outcomes, perceptions, and experiences) and diagnosis in children under 6 years of age from international peer-reviewed published manuscripts to facilitate a wider and more thorough understanding of this practice from a diverse sample of parents, children, and health care providers to inform and direct practice within NZ.

Research Question

What is best practice in testing and diagnosing COVID-19 in children under 6 years of age and what are the implications for practice in NZ?

Research Design

This study design is a systematic literature review. Systematic literature reviews take a systematic approach to reviewing current research to show what is known about a subject and what requires further research. Whittemore and Knafl (2005) state that "systematic reviews are research reviews that combine the evidence of multiple studies regarding a specific clinical problem to inform clinical practice and are the method of choice for evidence-based practice initiatives" (p. 547). A systematic literature review can synthesise and critique studies to present evidence to answer a replicable research question (Siddaway et al., 2019). This is useful for informing practice, especially to make sense of a vast array of scientific information available, and gives a wider picture of a phenomenon than a single study alone (Pati & Lorusso, 2018; Siddaway et al., 2019). A systematic review must be performed with rigour and transparency and address quality, bias, and credibility issues (Pati & Lorusso, 2018; Siddaway et al., 2019). This systematic review followed the key stages recommended by Siddaway et al. (2019), as presented in Table 1.

Table 1

Systematic Process

Stage	
1	Develop a clear, specific, and answerable research question
2	Clarify a present gap in the literature and familiarise oneself with the literature
3	Formulate unambiguous search terms that operationalise your research questions
4	Gain librarian research database searching support
5	Formulate preliminary inclusion and exclusion criteria
6	Undertake an initial search through more than two databases to then finalise the inclusion and exclusion criteria
7	Create clear record-keeping systems and keep consistent and meticulous records by working systematically
8	Adhere to recommended reporting standards (CONSORT or PRISMA)
9	Undertake final search using AND and OR Boolean search operators with associated filters (language, peer-reviewed, language, full text) through four databases relevant to the topic area
10	Initial screening through title and abstract
11	Secondary screening through full manuscript
12	Check reference lists of all included manuscripts for other potential studies
13	Critical appraisal score of all included manuscripts
All steps are undertaken in a systematic process by a minimum of two researchers independently, where researchers come together at each step to discuss results and reach a consensus of agreement.	

Note. Adapted from "How to do a Systematic Review: A Best Practice Guide for Conducting and Reporting Narrative Reviews, Meta-Analyses, and Meta-Syntheses" by A. P. Siddaway, A. M. Wood, & L. V. Hedges, 2019, *Annual Review of Psychology*, *70*(1), 747–770. https://doi.org/10.1146/annurev-psych-010418-102803

Sample

The sample, phenomenon of interest, design, evaluation and research (SPIDER) tool was utilised in this systematic review, as presented in Table 2 (National Collaborating Centre for Methods and Tools, 2013).

Table 2

The SPIDER Tool

Search Component	Description
Sample	Children under 6 years of age
Phenomenon of interest	COVID-19 testing
Design	Systematic literature review
Evaluation	Best practice/efficacy/outcomes/perceptions/experience
Research type	Qualitative or quantitative

Search Strategy

Phase 1: Initially a search was undertaken for full-text peer reviewed literature published in English between 2020 to 2024 on COVID-19 testing and/or diagnosis in children (0-18 years) and adults (Baldanti et al., 2022; Chhibber et al., 2020; Christophers et al., 2022; Fujita-Rohwerder et al., 2022; Mansourian et al., 2021; Roversi et al., 2022; Vandenberg et al., 2021). A content analysis was conducted independently by the student

and supervisor where the most reported concepts on COVID-19 testing and/or diagnosis were identified from the reviews and grouped into key topic areas (Thomas, 2006). These seven key areas being symptomology, diagnostic tests, efficacy and acceptability of testing, viral loads, health outcomes, vulnerability/risk factors, and recommendations, became the template for the deductive analysis. If there was any discrepancy on key areas identified, this was discussed between the student and supervisor until a consensus was reached.

Phase 2: A literature search was undertaken in four databases: CINAHL Complete (EBSCO), MEDLINE via PubMed, Scopus, and PsycINFO (Ovid). Although the literature in these databases is not limited to nursing, these databases contain relevant literature pertinent to nursing and healthcare and were chosen on this basis.

The search terms used when searching each database are presented in Table 3.

Table 3

Search Terms

Search number	Search terms
1	covid-19 AND (testing AND methods) OR covid-19 AND test*
AND	
2	preschool OR kindergarten OR (early AND childhood) OR child* OR neonate OR infant OR newborn OR baby
AND	
3	(best AND practices) OR guidelines OR (evidence-based AND practice) OR efficacy OR effectiveness OR impact OR benefits OR outcomes OR satisfaction OR experience OR perception OR view
AND	
4	(primary AND healthcare) OR (primary AND health AND care) OR (primary AND care) OR (general AND practice) OR gp OR (secondary AND healthcare) OR (outpatient AND clinics) OR (ambulatory AND care) OR (outpatient AND services) OR (outpatient AND care) OR hospital OR (acute AND setting) OR inpatient OR ward

Consultation with an AUT librarian was undertaken regarding general searches and search terms to verify the search and see if findings could be further refined (Table 1, Stage 4). The librarian confirmed that this search would adequately answer the research question and suggested further consultation with a specialist librarian. Further consultation was undertaken with a specialist librarian from AUT on searching medical databases. The specialist librarian suggested very few refinements, cautioned against exclusions depending on the range of findings, and confirmed that the search was robust (Table 1, Step 4).

Inclusion Criteria

- English language
- Full text
- Peer-reviewed published studies

- Studies that pertain to the research question
- Studies published between January 2020 and January 2024

Exclusion Criteria

- Literature reviews or studies that did not contain original empirical data
- Studies that did not pertain to the research question
- Studies in which data for age groups under 6 years old could not be extrapolated
- Studies which only contained positive COVID-19 children, that is, participants were diagnosed with COVID-19 prior to inclusion
- Studies outside of the inclusion dates

Search Outcome

Phase 2: Once the search criteria were identified and the search terms were applied to all four chosen databases, the resulting studies were imported into an Endnote library to identify duplicates which were then removed. PsycINFO results were manually screened for duplicates, as the search resulted in only two studies. All studies were screened by title and abstract, and studies that did not meet the inclusion criteria were excluded. The student and supervisor reviewed all studies independently to ensure a rigorous process. If there was any doubt that a study met the inclusion criteria, the study was discussed by the student and supervisor until a consensus was reached. The reference lists of all included studies were screened for any further potential studies, with any new articles highlighted, reviewed, and screened as per the previous criteria outlined in Table 1. The PRISMA flowchart was used to ensure transparent reporting of searches undertaken (Page et al., 2021).The final number of included studies was 14.

While selecting relevant studies, the aim was not to be exclusive in the search, enabling a more holistic and practical approach. Keywords such as “accuracy”, “sensitivity”, and “performance” produced diagnostic accuracy studies and excluded much of the accepted and holistic view of COVID-19 testing that was desired for inclusion. Therefore, these phases were not used. Studies that included all age ranges were excluded where possible; however, some studies included the required ages within the specified ranges. Finding research that included children younger than 6 years was challenging, as most studies were undertaken with children older than 6 years.

Critical Review of Studies

All studies were quality appraised using the Joanna Briggs Institute (JBI) appraisal tool (Aromataris et al., 2020). Each study was independently reviewed by the student and supervisor and compared. All findings are included in the Findings chapter and Appendix A. No studies were excluded based on their JBI score.

Data Extraction

Data relevant to answering the research question (author, year, aim, design, participants, data collection methods, findings, and JBI score) were extracted and are presented in the Findings chapter and Appendix A. While many studies included other age ranges, the data reviewed and extrapolated for this review only included the reported findings for the under 6-year-old age range.

Data Synthesis

Once data was extracted from the studies, it was synthesised using deductive analysis**,** also known as a priori analysis or top-down approach**,** involves applying pre-determined codes/categories to data based on theoretical concepts from the literature (Bingham & Witkowsky, 2022). Therefore, in the deductive approach categories were selected or specified before the collected literature was analysed and analysis was informed by these theoretical concepts. In this review the deductive approach was informed by child and adult COVID-19 literature which described these areas as key considerations for managing and addressing COVID-19 effectively. Deductive analysis is useful in exploring existing literature on a phenomenon of interest to ensure a systematic rigorous approach with data organisation (Bingham & Witkowsky, 2022) Once data were extracted from the included studies, findings were explored and collated under seven key areas being of symptomology, diagnostic tests, efficacy and acceptability of testing, viral loads, health outcomes, vulnerability/risk factors and recommendations as per a deductive descriptive analysis. Final recommendations for practice were then considered from these areas with consideration for current clinical guidelines and grey material and culture within NZ.

Ethical Considerations

Ethical approval was not sought for this systematic review as secondary data was used. However, all included studies had been reviewed by the appropriate ethics and board committees prior to the research commencing (Chiwandire et al., 2023; Cohen et al., 2020; Engels et al., 2022; Forster et al., 2022; Fougère et al., 2021; Hurst et al., 2021; Kumar et al., 2022; Lee et al., 2023; Moraleda et al., 2022; Oliver et al., 2021; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022) apart from Olivar-López et al. (2020) who stated confidentiality around data management but did not to list an approved ethics committee approval statement.

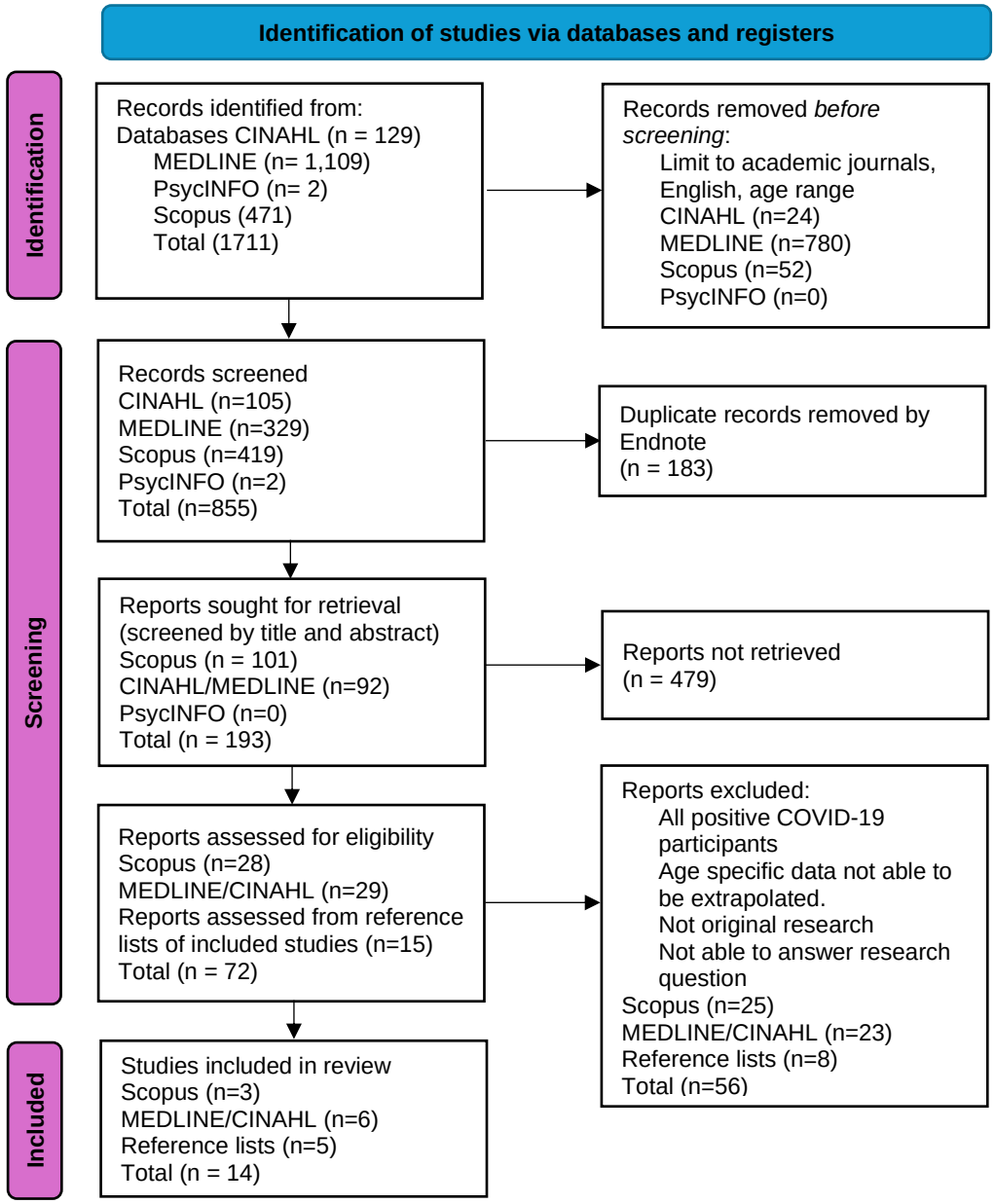
Findings

The search identified 1711 studies through CINAHL, SCOPUS, MEDLINE, and PsycINFO databases. After duplicates (*n* = 183) were removed, 672 articles remained to be screened by title and abstract. 479 studies were removed from the first screen as they did not meet the inclusion criteria. After a full review of each manuscript (second screen), 72 studies were reviewed by full manuscript (second screen), resulting in nine studies being included. On checking the included studies' reference lists, a further five studies were included, as illustrated in Figure 1. This systematic review included a total of 14 studies (Chiwandire et al., 2023; Cohen et al., 2020; Engels et al., 2022; Forster et al., 2022; Fougère et al., 2021; Hurst et al., 2021; Kumar et al., 2022; Lee et al., 2023; Moraleda et al., 2022; Olivar-López et al., 2020; Oliver et al., 2021; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022).

Figure 1

PRISMA Flowchart

PRISMA 2020 flow diagram for new systematic reviews which included searches of databases



From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/

Characteristics of Included Studies

The study designs included two prevalence studies (Chiwandire et al., 2023; G. Y. Zhou et al., 2022), three analytical cross-sectional studies (Cohen et al., 2020; Lee et al., 2023; Olivar-López et al., 2020), four quasi-experimental studies (Engels et al., 2022; Forster et al., 2022; Hurst et al., 2021; Westbrook et al., 2022), and five diagnostic test accuracy studies (Fougère et al., 2021; Kumar et al., 2022; Moraleda et al., 2022; Oliver et al., 2021; Weng et al., 2021) (see Appendix A).

These studies were undertaken in a diverse range of countries and included various participant recruitment methods and sample sizes. Chiwandire et al. (2023) was an epidemiology study where data was collected from databases throughout South Africa during the first four waves of the COVID-19 pandemic, where the

population estimates for those under 5 years of age was 5,708,956. Cohen et al. (2020) recruited 605 participants from 27 primary care paediatricians in Paris, France, with 410 participants under 6 years of age. Engels et al. (2022) and Forster et al. (2022) conducted their studies in nine childcare centres in Würzburg, Germany. Engels et al. (2022) conducted their study between May and July 2021, which involved parental self-reported data of 452 children aged 2–5 years. Forster et al. (2022) conducted their study between October 2020 and March 2021 with 442 children under 5 years of age using a volunteer recruitment method. Fougère et al. (2021) recruited children aged 1 month to 18 years from two different outpatient clinics in Lausanne, Switzerland. In their study, 31/397 were aged under 6 years of age. Hurst et al. (2021) recruited children who had confirmed COVID-19 or close contact with COVID-19 across the Duke University Health System in North Carolina, including three hospitals and more than 100 outpatient clinics from April to July 2020. This study included 87/293 children under 5 years of age infected with COVID-19 and 89/293 uninfected children (Hurst et al., 2021). Kumar et al.'s (2022) study was undertaken in a neonatal unit that included 1,225 neonates up to 44 weeks postmenstrual age in Chandigarh, India, from August to December 2020. Initially, COVID-19 testing in this study was only performed if the mother tested positive, if the baby was in close contact with a COVID-19 positive person within the previous 14 days, or had a severe respiratory illness. However, after 3 weeks, COVID-19 testing was performed on all symptomatic patients. Lee et al. (2023) included parents of 217 children from 26 early childhood centres in Arizona, USA. Childcare centres were selected based on eligibility for food assistance programmes due to lower socioeconomic status and geographical location. Moraleda et al. (2022) included children under 18 years of age with symptoms of COVID-19 (lasting for less than 5 days) from 10 hospitals in Madrid or Almeria, Spain, between February and March 2021. A total of 516/1,174 participants were aged 3 years or younger. Olivar-López et al. (2020) conducted their study in a paediatric emergency department in Mexico City between March and June 2020 and included 282 children under 5 years of age with any COVID-19 symptoms and who received a PCR COVID-19 test. Oliver et al. (2021) recruited 129 children under 5 years of age from three clinics in Melbourne, Australia, between July and September 2020. The authors prioritised recruiting people with COVID-19 or those who reported close contact with COVID-19. Weng et al. (2021) recruited 155 children under 4 years of age between March and June 2020 from 10 clinics in Rhode Island, USA. Participants who presented for evaluation of COVID-19 symptoms or who had been exposed to COVID-19 underwent a PCR test (Weng et al., 2021). Westbrook et al. (2022) recruited children under 18 years of age from six ambulatory testing sites in Georgia, USA, between July and October 2021, where 112 children aged 4 years or younger presented for COVID-19 testing. G. Y. Zhou et al. (2022) recruited 960 children under 4 years of age who presented for COVID-19 testing at one of three outpatient sites in Northern California by being referred by a nurse or outpatient provider between April and November 2020.

Critical Appraisal Scores

The JBI critical appraisal scores were 8–9/9 for the two prevalence studies, 7–8/9 for the four quasi-experimental studies, 6–8/8 for the three analytical cross-sectional studies, and 7–9/10 for the five diagnostic test accuracy studies, as presented in Table 4. It is unclear in Fougère et al. (2021) and Moraleda et al. (2022) whether participants were enrolled consecutively or randomly. There were no control groups in any of the quasi-experimental studies (Engels et al., 2022; Forster et al., 2022; Hurst et al., 2021; Westbrook et al., 2022) and Westbrook et al. (2022) did not have multiple outcome measurements. In addition, confounding factors were not specified or accounted for in Olivar-López et al. (2020), and it was unclear how loss of follow-up was accounted for in Engels et al. (2022).

Table 4

Joanna Briggs Critical Appraisal Scores

Study	Study type and JBI appraisal score	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Chiwandire et al. (2023)	Prevalence study, 8/9	✓	✓	✓	✓	✓	✓	✓	✓	N/A	
Cohen et al. (2020)	Analytical cross-sectional study, 8/8	✓	✓	✓	✓	✓	✓	✓	✓		
Engels et al. (2022)	Quasi-experimental study, 7/9	✓	✓	✓	X	✓	U/C	✓	✓	✓	
Forster et al. (2022)	Quasi-experimental Study, 8/9	✓	✓	✓	X	✓	✓	✓	✓	✓	
Fougère et al. (2021)	Diagnostic test accuracy study, 7/10	U/C	✓	✓	N/A	✓	✓	N/A	✓	✓	✓
Hurst et al. (2021)	Quasi-experimental study, 7/9	✓	✓	✓	X	N/A	✓	✓	✓	✓	
Kumar et al. (2022)	Diagnostic test accuracy study, 6/10	✓	✓	X	X	X	✓	X	✓	✓	✓
Lee et al. (2023)	Analytical cross-sectional study, 8/8	✓	✓	✓	✓	✓	✓	✓	✓		
Moraleda et al. (2022)	Diagnostic test accuracy study, 9/10	U/C	✓	✓	✓	✓	✓	✓	✓	✓	✓
Olivar-López et al. (2020)	Analytical cross-sectional study, 6/8	✓	✓	✓	✓	X	X	✓	✓		
Oliver et al. (2021)	Diagnostic test accuracy study, 9/10	✓	X	✓	✓	✓	✓	✓	✓	✓	✓
Weng et al. (2021)	Diagnostic test accuracy study, 9/10	✓	✓	✓	✓	✓	✓	✓	✓	✓	N/A
Westbrook et al. (2022)	Quasi-experimental study, 7/9	✓	✓	✓	X	X	✓	✓	✓	✓	
G. Y. Zhou et al. (2022)	Prevalence study, 9/9	✓	✓	✓	✓	✓	✓	✓	✓	✓	

Note. ✓ = Yes; X = No; N/A = Not applicable; U/C = Unclear.

Seven areas in relation to answering the research question of "What is currently the best practice in testing for COVID-19 in children under 6 years of age, and what are the implications for practice in NZ?" were deductively generated from 14 manuscripts. These were: symptomology (Cohen et al., 2020; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022); diagnostic tests (Chiwandire et al., 2023; Cohen et al., 2020; Engels et al., 2022; Forster et al., 2022; Fougère et al., 2021; Kumar et al., 2022; Moraleda et al., 2022; Olivar-López et al., 2020; Oliver et al., 2021; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022); efficacy and acceptability of testing (Engels et al., 2022; Forster et al., 2022; Fougère et al., 2021; Kumar et al., 2022; Lee et al., 2023; Moraleda et al., 2022); viral loads (Forster et al., 2022; Fougère et al., 2021; Hurst et al., 2021); health outcomes (Chiwandire et al., 2023; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020); vulnerability/risk factors

(Chiwandire et al., 2023; Cohen et al., 2020; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022); and recommendations (Chiwandire et al., 2023; Cohen et al., 2020; Engels et al., 2022; Forster et al., 2022; Fougère et al., 2021; Hurst et al., 2021; Kumar et al., 2022; Lee et al., 2023; Moraleda et al., 2022; Olivar-López et al., 2020; Oliver et al., 2021; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022).

Symptomology

Out of the 14 studies included in this review, seven reported on symptomology in the diagnosis of COVID-19 for under 6-year-olds (Cohen et al., 2020; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022) as presented in Table 5. Hurst et al. (2021) reported that 75% of children under 5 years of age had symptoms reported at enrolment (any symptoms experienced 14 days prior) or present at follow-up (7 days post enrolment), with the median duration of symptoms being 4 days. In terms of specific symptoms observed in COVID-19 positive children aged 0–5 years, fever presented in 52%, respiratory symptoms in 48% (cough 30%, difficulty breathing 8%, nasal congestion 14%, rhinorrhoea 16%), influenza-like symptoms 6% (headache 5%, myalgias 1%, pharyngitis 1%), gastrointestinal symptoms in 17% (abdominal pain 6%, diarrhoea 13%, vomiting 5%), sensory symptoms in 0% (anosmia, dysgeusia), other symptoms in 18% (arthralgias 2%, chest pain 0%, conjunctivitis 2%), and rash in 7% (Hurst et al., 2021). Of interest, fever and respiratory symptoms were reported more frequently by the 0–5-year age group than other children aged from 6–13 and 14–20 years. When plotted on a graph, children in this age group decreased their number of symptoms over days of infection more rapidly than older children (Hurst et al., 2021). Out of 410 children (0–5 years) in the Cohen et al. (2020) study, 6/8 infants under 3 months of age were pauci-symptomatic (having a fever isolated or associated with respiratory signs, such as cough, dysphagia, rhinorrhoea, diarrhoea, vomiting, rash, dysgeusia or anosmia during the prior 7 days), 0/8 were previously symptomatic (nil symptoms in the prior 7 days but had symptoms [fever, digestive or respiratory] from 2 months to 7 days prior to enrolment) and 2/8 were asymptomatic (nil symptoms prior). In the 3–30-month age bracket, 98/218 were pauci-symptomatic, 37/218 were previously symptomatic, and 83/218 were asymptomatic. In the 31-month to 5-year age bracket, 96/184 were pauci-symptomatic, 34/184 were previously symptomatic, and 54/184 were asymptomatic (Cohen et al., 2020).

Of interest, Kumar et al. (2022) investigated 1,225 neonates presenting to an emergency department in India; 875 (71.4%) neonates presented with respiratory distress on admission, with most of the neonates (486/1,225) presenting on day one of life. Of the COVID-19 positive infants, 3/17 presented with a fever (>38°C), 15 with respiratory distress, and none with a cough, yet 16/952 non-COVID-19 neonates presented with a fever, 670 with respiratory distress, and 3 with a cough. COVID-19 positive neonates had respiratory distress at day 2 compared to day 1 of non-COVID-19 positive infants who were admitted at an older age (day 11 versus day 3). Febrile neonates were more likely to be positive for COVID-19 (OR: 12.5; 95% confidence

interval [CI]: 3.3–47.9, p = .004). However, no difference was noticed in respiratory distress, cough, prior hospitalisation, or need for ventilation between COVID-19 positive and negative infants.

Olivar-López et al. (2020) observed the following symptoms in 41/282 COVID-19 positive children (25 neonates < 2 years old and 16 pre-schoolers): fever in 48% of neonates, 75% of pre-schoolers; cough in 52% of neonates, and 38% of pre-schoolers; dyspnoea in 28% of neonates, and 13% of pre-schoolers; irritability in 52% of neonates, and 44% of pre-schoolers; diarrhoea in 16% of neonates, and 31% of pre-schoolers; shivers in 4% of neonates, and 44% of pre-schoolers; general malaise in 28% of neonates, and 38% of pre-schoolers; rhinorrhoea in 16% of neonates, and 25% of pre-schoolers; polypnea in 44% of neonates, and 13% of pre-schoolers; vomiting in 20% of neonates, and 19% of pre-schoolers; conjunctivitis in 12% of neonates, and 13% of pre-schoolers; cyanosis in 8% of neonates, and 6% of pre-schoolers; sudden onset of illness in 68% of neonates, and 88% of pre-schoolers. Of interest, symptoms reported in non-COVID-19 positive children in pre-schoolers were odynophagia (25%), chest pain (6%), headache (31%), myalgia (19%), arthralgia (6%), and abdominal pain (44%). There were 25/148 COVID-19 positive cases in children aged under 2 years and 16/134 pre-schoolers who were COVID-19 positive in this study (Olivar-López et al., 2020).

G. Y. Zhou et al. (2022) calculated the positive likelihood ratio (PLR) for children who presented with a symptom and were likely to test positive for COVID-19 in the 0–4-year-old age group. These symptoms included fever/chills (54.6%, PLR 1.3, 95% CI: 1.11–1.54, p < .05), cough (38.6%, PLR 0.77, 95% CI: 0.54–1.09), nausea/vomiting or diarrhoea (23.5%, PLR 0.77, 95% CI: 0.47–1.25), sore throat (12.7%, PLR 1.4, 95% CI: 0.70–2.77), headache (5.9%, PLR 0.7, 95% CI: 0.17–2.86), shortness of breath (1.0%, PLR 2.91, 95% CI: 0.63–13), nasal congestion/rhinorrhoea (51.6%, PLR 1.05, 95% CI: 0.85–1.31), fatigue (20.2%, PLR 1.37, 95% CI: 0.51–3.73), muscle aches (3.3%, PLR 1.66, 95% CI: 0.60–4.61), loss of taste or smell (0.1%, PLR 0.00, 95% CI: 0.16–93), rash (4.7%, PLR 0.92, 95% CI: 0.29–2.91), conjunctivitis (1.7%, PLR 1.54, 95% CI: 0.20–12), abdominal pain (9.8%, PLR 0.63, 95% CI: 0.20–1.95), and self-reported COVID-19 contact (18.4%, PLR 5.87, 95% CI: 4.67–7.38, p < .05). This study had 76/960 COVID-19 positive children aged 0–4 years. Most symptoms in all age groups did not have a positive likelihood of association with COVID-19, including common symptoms such as nasal congestion (G. Y. Zhou et al., 2022).

Westbrook et al. (2022) found no significant difference in the incidence of COVID-19 in children displaying 0, 1, or 2 or more symptoms of COVID-19 in terms of age, race, or ethnicity in 112 children aged between 0 and 4 years. Infants or pre-schoolers with only 1 symptom were 4.32 OR (95% CI: 0.71–26.13) times as likely to test positive for COVID-19 as children with no symptoms (p = .11). Infants or pre-schoolers with ≥ 2 symptoms were 1.63 OR (95% CI: 0.33–8.02) times as likely to test positive for COVID-19 as children with no symptoms (p = .55). Interestingly, children with ≥ 2 symptoms were no more likely to test positive for COVID-19 compared to children with only 1 symptom 0.38 OR (95% CI: 0.11–1.30) (p = .12). In essence, infants and pre-schoolers having 1 or 2 or more symptoms were no more likely to test positive for COVID-19 than asymptomatic children, and this was the same when comparing to children with 1 or more than 2 symptoms.

Asymptomatic children in this study had an incidence of 2/21 (9.5%) for testing positive for COVID-19 with 1 symptom 5/15 (31.3%), and with 2 or more symptoms 11/75 (14.7%).

Weng et al. (2021) observed 155 children in the 0–4 year age group. Children who experienced prior exposure to COVID-19 were the highest predictor for identifying COVID-19. They reported no individual or combination of symptoms that were statistically significant to predict a COVID-19 infection. In children under 5 years of age, fever and cough had the highest sensitivity for COVID-19 predictors at 70% and 65%, respectively; however, specificity was 46.5% for fever and 72.8 % for cough (Weng et al., 2021). In children aged 0–4 years infected with COVID-19, Weng et al. (2021) found the presence of cough in 65%, fever in 70%, congestion or rhinorrhoea in 37.5%, dyspnoea in 17.5%, diarrhoea in 20%, fatigue in 7.5%, and vomiting in 7.7%, with a total number of 40 COVID-19 positive children out of 155 suspected (Weng et al., 2021).

Fever, chills, or shivers were discussed in four studies, as were congestion, rhinorrhoea, dyspnoea, difficulty breathing, cough, and diarrhoea (Hurst et al., 2021; Olivar-López et al., 2020; Weng et al., 2021; G. Y. Zhou et al., 2022). Headaches were discussed in three studies, as were conjunctivitis, abdominal pain, and muscle aches/arthralgia/myalgia (Hurst et al., 2021; Olivar-López et al., 2020; G. Y. Zhou et al., 2022). Vomiting/nausea were discussed in three studies (Hurst et al., 2021; Weng et al., 2021; G. Y. Zhou et al., 2022). Fatigue or general malaise was also discussed in three studies (Olivar-López et al., 2020; Weng et al., 2021; G. Y. Zhou et al., 2022). Pharyngitis or sore throat was discussed in two studies (Hurst et al., 2021; G. Y. Zhou et al., 2022). Two studies also discussed rash (Hurst et al., 2021; G. Y. Zhou et al., 2022). Odynophagia, chest pain, and irritability were only discussed in the Olivar- López (2020) study. Abdominal distention and shock were only described in the Kumar et al. (2022) study. Table 5 represents the incidence of symptomatology reported within the seven studies.

Table 5

Symptomatology Representativeness

Symptom	Cohen et al. (2020)	Hurst et al. (2021)	Kumar et al. (2022)	Olivar-López et al. (2020)	Weng et al. (2021)	Westbrook et al. (2022)	G. Y. Zhou et al. (2022)
Fever, chills, shivers	X	X	X	X	X	X	X
Congestion, rhinorrhoea	X	X		X	X	X	X
Dyspnoea, difficulty breathing		X	X	X	X	X	X
Cough	X	X	X	X	X	X	X
Headaches		X		X		X	X
Pharyngitis, sore throat		X				X	X
Abdominal pain		X		X		x	X
Diarrhoea	X	X		X	X	X	X
Vomiting	X	X	X	X	X	X	

Symptom	Cohen et al. (2020)	Hurst et al. (2021)	Kumar et al. (2022)	Olivar-López et al. (2020)	Weng et al. (2021)	Westbrook et al. (2022)	G. Y. Zhou et al. (2022)
Muscle aches, arthralgia, myalgia		X		X		X	X
Conjunctivitis		X		X			X
Rash	X	X					X
Fatigue, general malaise				X	X	X	X
Other	X (Dysgeusia, anosmia, dysphagia)		X (Abdominal distention, shock)	X (Odynophagia, chest pain, irritability)		X (Photophobia, loss of taste or smell, nausea)	X (Loss of taste or smell)

Note. X represents the symptom evident in the study.

Diagnostic Tests

Various COVID-19 screening and testing methods were used across the 14 studies included in this review. The tests used were SARS-CoV-2 PCR (oro/nasopharyngeal), COVID-19 saliva test, rapid antigen test (RAT), finger prick blood serology, self-reported COVID-19 contact, contact tracing, symptomatology, comorbidities, vaccination against influenza, and vaccination against COVID-19 as seen in Table 6. The most common test used was the PCR (either oropharyngeal or nasopharyngeal), as evident in 12 studies (Chiwandire et al., 2023; Cohen et al., 2020; Forster et al., 2022; Fougère et al., 2021; Hurst et al., 2021; Kumar et al., 2022; Moraleda et al., 2022; Olivar-López et al., 2020; Oliver et al., 2021; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022), followed by symptomatology in seven studies (Cohen et al., 2020; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). COVID-19 saliva testing was used in six studies (Engels et al., 2022; Forster et al., 2022; Fougère et al., 2021; Lee et al., 2023; Moraleda et al., 2022; Oliver et al., 2021). Saliva testing comprised of self-sampled mouth rinsing fluid (Engels et al., 2022; Forster et al., 2022), drooling saliva (Fougère et al., 2021; Lee et al., 2023), or an oral saliva swab rubbed on the inside of the child's mouth (Moraleda et al., 2022; Oliver et al., 2021). RATs were used in three studies (Chiwandire et al., 2023; Engels et al., 2022; Moraleda et al., 2022). These tests were nasal in Engels et al. (2022), nasopharyngeal in Moraleda et al. (2022) and unknown, presumed nasal in Chiwandire et al. (2023). Finger prick blood serology to check for COVID-19 antibodies was used in three studies (Cohen et al., 2020; Engels et al., 2022; Forster et al., 2022), whereas self-reported confirmed COVID-19 and contact (Cohen et al., 2020; Oliver et al., 2021; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022) or self-reported confirmed COVID-19 contact and suspected contact were only recorded in one study (Westbrook et al., 2022).

Kumar et al. (2022) performed contact tracing on parents of neonates who were COVID-19 positive; this was the only study to report on parental COVID-19 status for COVID-19 positive infants. This resulted in 5 mothers and 1 father being COVID-19 positive, where 4 mother/father dyads were not tested (Kumar et al., 2022). Hurst et al. (2021) used contact tracing to find participants from already known COVID-19 positive individuals.

Comorbidities were reported in five studies (Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; G. Y. Zhou et al., 2022). Olivar-López et al. (2020) reported on the influenza vaccine as a variable in outcomes, whereas Westbrook et al. (2022) included COVID-19 vaccination in their reported analysis, although not broken down by age and it is unclear if any under 5-year-olds in this cohort had received a vaccine.

Table 6

Screening Tests Utilised

Screening/Testing tool used	Studies
SARS-CoV-2 PCR	Chiwandire et al. (2023); Cohen et al. (2020); Forster et al. (2022); Fougère et al. (2021,); Hurst et al. (2021); Kumar et al. (2022); Moraleda et al. (2022); Olivar-López et al. (2020); Oliver et al. (2021); Weng et al. (2021); Westbrook et al. (2022); G. Y. Zhou et al. (2022)
COVID-19 saliva test	Engels et al. (2022); Forster et al. (2022); Fougère et al. (2021); Lee et al. (2023); Moraleda et al. (2022); Oliver et al. (2021)
Rapid antigen test	Chiwandire et al. (2023); Engels et al. (2022); Moraleda et al. (2022)
Fingerprick blood serology test	Cohen et al. (2020); Engels et al. (2022); Forster et al. (2022)
Self-reported positive contact	Cohen et al. (2020); Oliver et al. (2021); Weng et al. (2021); Westbrook et al. (2022); G. Y. Zhou et al. (2022)
Contact tracing	Hurst et al. (2021); Kumar et al. (2022)
Symptomatology	Cohen et al. (2020); Hurst et al. (2021); Kumar et al. (2022); Olivar-López et al. (2020); Weng et al. (2021); Westbrook et al. (2022); G. Y. Zhou et al. (2022)
Comorbidities	Hurst et al. (2021); Kumar et al. (2022); Olivar-López et al. (2020); Weng et al. (2021); G. Y. Zhou et al. (2022)
Vaccinated against influenza	Olivar-López et al. (2020)
Vaccinated against COVID-19	Westbrook et al. (2022)

Note. PCR = Polymerase chain reaction (Oro/Nasopharyngeal); RAT = Rapid Antigen Test.

Efficacy and Acceptability of Testing

Two studies looked at test efficacy in under 6-year-olds (Fougère et al., 2021; Moraleda et al., 2022) and three studies reported on the acceptance of COVID-19 testing in children under 6 years of age (Engels et al., 2022; Forster et al., 2022; Lee et al., 2023). Kumar et al. (2022) also reviewed their selection policy for the efficacy of COVID-19 detection in neonates, and Forster et al. (2022) and Engels et al. (2022) discussed the efficacy of screening tests to prevent the spread of COVID-19. Fougère et al. (2021) reported that 4/31 children tested positive for COVID-19 on nasopharyngeal swabs (NPS), 1 on saliva swab (p = .110, 95% CI: -11.1% to 0.7%), and only 15 children were able to drool saliva for a sample. The authors suggested a limit in diagnostic performance in any sample taken from children under 6 years of age and those with symptom duration longer than 4 days (Fougère et al., 2021). Forster et al. (2022) addressed efficiency by calculating the estimated infection spread in childcare centres based on parameters identified in their study and the literature. This estimation model included testing frequencies and participation rates for three scenarios (patient being a COVID-19 positive child, childcare worker being symptomatic, or childcare worker

asymptomatic). They reported that higher participation rates and higher test frequencies reduced the spread of COVID-19, but the efficacy of surveillance depended on the rapid reporting of results (Forster et al., 2022). Forster et al. (2022) separated participants into four modules. Module 1 was twice weekly COVID-19 mid-turbinate nasal swabs, module 2 was once weekly mid-turbinate nasal swabs, module 3 was a twice weekly self-sampled mouth rinsing saliva test, and module 4 was symptomatic oropharyngeal swabs. Successful participation was rated at 60% of all samples taken and was highest in module 3. Module 3 had a 65.4% successful completion rate, module 2 had a 31.7% successful completion rate, and module 1 had only 33.3% successful completion rate. Dropout rates were 18% in module 1, 20% in module 2, and 4% in module 3. Acceptance for continuous surveillance was highest for biweekly saliva testing (150 of 221 eligible individuals [67.9%; 95% CI: 61.5–73.7%]) compared with biweekly (51 of 117 individuals [43.6%; 95% CI: 35.0-52.6%]) and weekly (44 of 128 individuals [34.4%; 95% CI: 26.7–43.0%]) mid-turbinate swabbing ($p < .001$) (Forster et al., 2022). The main reason for dropout was the refusal of sampling from children. On completion of the study, parents in modules 1–3 viewed the positive effects slightly higher than those in module 4. Childcare workers were also more content with testing in modules 1–3 than in module 4.

Similarly, Engels et al. (2022) compared the incidence of COVID-19 in children attending any of the 69 childcare centres in Wuerzburg over 3 months. They calculated that the risk was small for population incidences up to 200 per 100,000, but it increased with incidences above this, especially in larger childcare centres. For the probability of at least one child with COVID-19 entering the childcare centre within 1 week to remain below or at a maximum level of 5%, the age-adjusted incidence must be less than 143, 95, and 71 for childcare centre sizes of 50, 75, and 100, respectively (Engels et al., 2022). In Engels et al. (2022), the rates of successful participation in COVID-19 testing varied per group. Group 1 involved saliva tests and RATs for COVID-19, acceptability was 60.9% (131/215); group 2 involved saliva-only testing, acceptability was 64.5% (111/172); and group 3 involved a RAT, acceptability was 44.6% (29/65). Participation decreased over time for all methods, particularly between weeks 9 and 12 of the study. For saliva tests, participation rates were 78.1% between weeks 1 and 4, 74.7% between weeks 5 and 8, and only 64.0% between weeks 9 and 12. Participation rates were lower for RATs, with 59.4%, 56.8%, and 47.5%, respectively. Most parents considered screening useful (86.4%), the frequency of testing appropriate (91.8%), and were satisfied with the self-sampling process (77.9%). Parents reported that saliva testing for COVID-19 had very good cooperation from their children (49.5%), and cooperation from children for RATs was 46.2%. In week 12, 73.6% of parents reported that their children did not like RATs (Engels et al., 2022). Lee et al. (2023) reported that rates of saliva testing acceptability were lower amongst children than adults (58.0% vs 73.2%). Parents reported that saliva testing was easy for their child for 25% of 3-year-olds, 45% of 4-year-olds, and 75% of 5-year-olds. Overall, 41 children could not produce a saliva sample and 83 could do so. Of these children, 81 found providing a sample not easy, and 62 found this easy to do by parent proxy. Of the children who could produce a sample, 17 were unhappy with the procedure, and 64 were happy. The child's age was significantly related

to outcomes as parents of older children (4–5-year-olds) were likelier to report that the test was easy, and older children were likelier to report the testing as fun and something they would do again (Lee et al., 2023).

Kumar et al. (2022) adopted a universal rather than selective testing protocol to help identify COVID-19 in neonates (PCR test) where of 969 cases, 17 neonates were positive for COVID-19 (1.8%, 95% CI: 1.03–2.79). By incorporating a universal protocol, an additional 8 neonates (47%) with COVID-19 were detected, and 9/17 (53%) neonates would have been identified if only a selective testing policy had been utilised. PCR testing was considered the gold standard for diagnostic accuracy and comparing the selective testing policy to this gold standard revealed a sensitivity of 52.9% (95% CI: 28.5–76.1), specificity of 83.3% (95% CI: 80.7–85.6), accuracy of 82.8% (95% CI: 80.3–85.1), a PLR of 3.17 (95% CI: 1.98–5.07), and a negative likelihood ratio (NLR) of 0.56 (95% CI: 0.34–0.93). Respiratory distress formed part of the selective testing policy, and when respiratory distress cutoffs were increased in the testing policy it significantly dropped the sensitivity to 41.2% (95% CI: 18.4–67.1) with 48 hours cut off, 35.3% (95% CI: 14.2–61.7) with 72 hours cutoff, while specificity was 87.4% (95% CI: 85.1–89.4) at 48 hours and 89.4% (95% CI: 87.5–91.3) at 72 hours for COVID-19 (Kumar et al., 2022).

Moraleda et al. (2022) evaluated oral saliva swabs (OSS) reverse transcription (RT) PCR compared to RT-PCR and RATs on nasopharyngeal swabs for detecting COVID-19 in children. The authors reported that an OSS PCR test showed similar accuracy performance in children, whereas a RAT showed lower sensitivity in children aged under 3 years. Sensitivity for the detection of COVID-19 for an OSS in children aged under 3 was 75% (95% CI: 47.6– 92.73%), specificity of 99.6% (95% CI: 98.6–99.9%), positive predictive value of 85.7% (95% CI: 59.4–96.1%), negative predictive value of 99.2% (CI 98.1–99.7%), PLR of 187.5 (95% CI: 45.7–769.4), and an NLR of 0.25 (95% CI: 0.11–0.59). RAT sensitivity in the same age group was 43.7% (95% CI: 19.8–70.1%), specificity of 100% (95% CI: 99.2–100%), positive predictive value of 100%, and negative predictive value of 98.2% (95% CI: 97.3–98.4%). Moraleda et al. (2022) stated that OSS is an accurate option for COVID-19 testing in children and showed higher sensitivity than the RAT.

Viral Loads

Viral loads were evident in three studies (Forster et al., 2022; Fougère et al., 2021; Hurst et al., 2021). In the study by Fougère et al. (2021) the viral loads from saliva were significantly lower when compared to the NPS (interquartile range, 1.2 × 104–5.2 × 105; interquartile range, 8.6 × 105 –1 × 108; vs median 8.7 cp/mL × 104; $p < .001$, 95% CI: -4.5 × 102 to -7.7 × 101; vs median 4.0 × 107 cp/mL). Hurst et al. (2021) found that COVID-19 was detected in 178 (69%) samples at a median (IQR) viral load of 4.0 log copies/mL (95% CI: 3.0–5.6). Nasopharyngeal viral load did not differ by age group ($p = .80$) or by symptomatic and asymptomatic children of any age (median [IQR]: 4.1 [3.0–5.5] vs 3.8 [2.8–6.5] log copies/mL; $p = .56$) and there was no association between viral load and specific symptoms such as fever, respiratory symptoms, or other groups of symptom complexes. In symptomatic children, NPS viral loads were found to be highest in the 3 days preceding and after the onset of the symptoms; this decreased with increased time since symptom onset. Forster et al.

(2022) used viral load data from other research to predict potential transmission in childcare centres and based calculations on a scenario where viral load in adults was higher than that of children.

Health Outcomes

Six studies reported on health outcomes of children who were COVID-19 positive (Chiwandire et al., 2023; Engels et al., 2022; Forster et al., 2022; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020). In the Hurst et al. (2021) study, one infant who had a prior history of bronchiolitis required hospitalisation for respiratory distress and was prescribed remdesivir. In the Kumar et al. (2022) study, 5 neonates died; 2 neonates had lethal congenital anomalies, and 3 died due to severe sepsis. The median length of hospital stay for a neonate with confirmed COVID-19 was 5 days (Hurst et al., 2021). No specific therapies were given in 16 of the neonates as the clinical features were either not attributed to COVID-19 or their condition was not severe enough to warrant this. One neonate had clinical and radiographical features consistent with COVID-19 pneumonia and was given a 5-day course of methylprednisolone. Olivar-López et al. (2020) reported that one patient who arrived at the emergency department in asystole with COVID-19 died, and a total of 11 patients in their study required mechanical ventilation.

Chiwandire et al. (2023) found that infants consistently had the highest cumulative hospital admission rate throughout all COVID-19 waves in South Africa. In the first three waves of COVID-19, adults had the highest weekly hospital admission rates, followed closely by infants, but in the fourth wave, infants exceeded adult rates and hospitalisation rates in children aged under 5 years increased (Chiwandire et al., 2023). The mortality from COVID-19 for under 1-year-olds was 0.3% and in children aged 1–4 years was 0.1%. Under 1-year-olds had a 34.1% rate of disease severity in the third wave and a 25.4% disease severity in the fourth wave. In the 1- to 4-year-old age group, disease severity was 20.6% in the third wave and 15.0% in the fourth wave. Under 1-year-olds had higher mortality in the first wave compared to the subsequent waves, whereas the 1-to-4-year-old group had the highest mortality in the second wave. Hospital admissions for under 1-year-olds testing positive for COVID-19 was 1.3%, and for 1–4-year-olds, the hospital admission rate was 1.2% (Chiwandire et al., 2023).

As well as the physical outcomes of COVID-19, two studies reported the psychological effects of COVID-19 testing (Engels et al., 2022; Forster et al., 2022). Forster et al. (2022) reported that indicators of depression and anxiety amongst parents of children remained the same in modules 1–3 (10 [9%] vs 13 [11.5%] of 113 parents) but increased in module 4 (symptomatic testing) (7 [5%] vs 18 [13%] of 138 parents; $p = .008$). Parents in modules 1–3 rated the positive effects of the surveillance higher than parents in module 4 and rated their sense of security improved (fairly or very affected, 100 of 129 parents [78%] vs 79 of parents 156 [51%]; $p < .001$) (Forster et al., 2022). In Engels et al. (2022), parental fear of COVID-19 transmission was 24% prior to the study and 16% feared that if infected, they would develop a severe infection of COVID-19. Only 6% had a critical view towards COVID-19 surveillance of their children and 12% feared negative consequences of the surveillance. Post surveillance period, parents felt that the danger of COVID-19 infection to themselves

or their family was decreasing (p = .013), as did their potential negative impacts of the testing measures used (p < .001). Parents also reported less fear regarding their own health, risk of a serious COVID-19 infection, and risk of transmission (all p = .005 or lower) (Engels et al., 2022).

Vulnerability/Risk Factors

Eight studies listed areas of vulnerability to COVID-19 which included contact with a COVID-19 positive person (Chiwandire et al., 2023; Cohen et al., 2020; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). Kumar et al. (2022) reported 5 neonatal deaths; however, there was no difference in the adjusted mortality rate between COVID-19 and non-COVID-19 cases, and although neonates who had confirmed COVID-19 were at a higher risk for all-cause mortality (95% CI: 1.1–8.9, p =.03; OR: 3.1), this difference was not deemed significant after adjustments to calculations were made for fatal congenital anomalies (95% CI: 0.7–8.7, p = .17; OR: 2.4) (Kumar et al., 2022). Olivar-López et al. (2020) reported that 11 patients required mechanical ventilation; however, the variables associated with ventilation were being under 2 years of age, a history of not having an influenza vaccination, sudden onset of symptoms, and a history of previous haemato-oncologic pathology. The only statistically significant variable was contact with a known positive COVID-19 person (27.6% vs 57.9%) (Olivar-López et al., 2020). G. Y. Zhou et al. (2022) reported that exposure to someone with COVID-19 gave a statistically significant PLR at all ages (5.87), and having fever or chills in the 0–4 year age group increased the OR of being COVID-19 positive, if adjusted for contact exposure. Weng et al. (2021) found that a known COVID-19 exposure had the highest area under the curve for COVID-19 identification in all age groups. A known COVID-19 exposure was present in 77.5% of 0–4-year-olds, with a calculated sensitivity of 77.5% and specificity of 72.8% (Weng et al., 2021). Cohen et al. (2020) reported that only 2/275 (0.7%) children without any contact with a person with COVID-19 had positive COVID-19 results. Chiwandire et al. (2023) found that having one or more comorbidities in the 0–4-year-old range in the fourth wave of COVID-19 resulted in a more severe case of disease when compared to the third wave (p = .001). Hurst et al. (2021) reported that a medical history of diagnosed asthma was more common in COVID-19 negative children than in COVID-19 positive children (17% vs 6%; p = .005). COVID-19 positive children were more likely to have contact with a COVID-19 infected sibling than uninfected children (49% vs 29%; p = .001) (Hurst et al., 2021). Westbrook et al. (2022) reported that children in early childhood with symptoms were no more likely to test positive for COVID-19 than children with no symptoms, and this pattern remained similar when fever or adjustment for exposure status and vaccination status were excluded.

Recommendations

All 14 included studies summarised their findings and provided recommendations (Chiwandire et al., 2023; Cohen et al., 2020; Engels et al., 2022; Forster et al., 2022; Fougère et al., 2021; Hurst et al., 2021; Kumar et al., 2022; Lee et al., 2023; Moraleda et al., 2022; Olivar-López et al., 2020; Oliver et al., 2021; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). These recommendations are summarised in Table 7.

Six studies highlighted future recommendations concerning the symptomatology, clinical contacts, and subsequent testing policy of COVID-19 in children (Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). Seven studies recommended types of testing, acceptance of testing, and testing efficacy (Cohen et al., 2020; Engels et al., 2022; Forster et al., 2022; Fougère et al., 2021; Lee et al., 2023; Moraleda et al., 2022; Oliver et al., 2021) and one study recommended vaccination of children for COVID-19 (Chiwandire et al., 2023).

Due to the age-related differences in the clinical manifestation of COVID-19 in children, the consequential screening strategies that needed to be considered when evaluating a child with COVID-19 differed across studies (Hurst et al., 2021). Olivar-López et al. (2020) suggested that infants with a sudden onset of symptoms or a history of contact with confirmed COVID-19 were primary factors in identifying whom to test for COVID-19, as these were associated with a positive test result. G. Y. Zhou et al. (2022) also agreed that the most significant likelihood factor of COVID-19 was exposure to the virus and suggested that a limited symptoms list could be useful for targeted COVID-19 testing. Westbrook et al. (2022) surmised that children with isolated symptoms were just as likely to have COVID-19 as those with multiple symptoms; however, their study had a small sample size of children under 4 years old and felt further research was needed to understand how generalised these findings could be. Weng et al. (2021) agreed about the limited diagnostic value of symptoms for COVID-19 in children and recommended the value of widely available COVID-19 testing. They also concluded that exposure to somebody infected with COVID-19 remains a highly predictive factor for contracting COVID-19 in children. Hurst et al. (2021) recommended further research into age-related differences in infection and susceptibility, as well as clinical characteristics in COVID-19 positive children. COVID-19 is difficult to distinguish from other illnesses in neonates, and a selective testing policy has poor diagnostic accuracy for COVID-19 (Kumar et al., 2022). Therefore, Kumar et al. (2022) suggested that contact tracing is important for COVID-19 in neonates.

Cohen et al. (2020) found that children with positive serology results for COVID-19 were more likely to have a positive PCR test. They suggested adding serology to testing as well as screening for household contacts with COVID-19 during the assessment process (Cohen et al., 2020). Fougère et al. (2021) concluded that the saliva test was performed poorly in younger children when testing for COVID-19. These authors suggest that the lower viral loads documented in children under 6 years of age and those with symptoms for more than 4 days likely limited the diagnostic performance of saliva (Fougère et al., 2021). Of note, children under 6 years of age were poorly represented in this study, and the authors noted their limited ability to make definitive suggestions for this age group (Fougère et al., 2021). Similarly, Lee et al. (2023) demonstrated that saliva is an acceptable testing method for COVID-19 in 4-and 5-year-olds; however, they felt that 3-year-olds may need different forms of testing. Oliver et al. (2021) suggested that saliva testing may be suitable as an adjunct to oropharyngeal or nasal testing in children under 10 years of age for COVID-19, but it is unlikely to have the sensitivity to be used alone for younger children.

Moraleda et al. (2022) showed that saliva swabs were more sensitive than a RAT for COVID-19 in younger children and concluded that saliva swabs are a suitable and patient-friendly technique for younger children, (especially those who need tested frequently) and will likely aid in the COVID-19 testing compliance. Forster et al. (2022) showed that long-term surveillance testing for COVID-19 was feasible and accepted by children and parents. Similarly, Engels et al. (2022) suggested that their findings of self-sampling and continuous surveillance testing for COVID-19 in daycare centres could be established on age-adjusted incident rates. Less invasive testing, such as saliva sampling, was more widely accepted and could be used in continuous testing for COVID-19 in under 5-year-olds. Chiwandire et al. (2023) only had one recommendation from their epidemiology study of COVID-19 in children in South Africa, which was to extend vaccination to the younger age group, especially in children who had at least one comorbidity.

Table 7

Recommendations from Included Studies

Author (Year)	Recommendations
Chiwandire et al. (2023)	Vaccination should be expanded to children aged 5–11 years with underlying illnesses.
Cohen et al. (2020)	The only factor associated with reverse transcription PCR COVID-19 or serology positivity was the presence of a household contact with COVID-19. The study highlights that the frequency of reverse transcription PCR COVID-19 positivity was significantly higher in children with positive than negative serology results. This finding highlights the difficulties in interpreting the significance of a positive reverse transcription PCR COVID-19 result without concomitant antibody testing after the epidemic wave.
Engels et al. (2022)	In this study, home-based continuous testing for COVID-19 by PCR from saliva samples and RAgT from nasal atrium was generally well accepted by children and CCWs. Less invasive saliva sampling was the preferred test method with the highest long-term acceptance levels. Testing acceptance declined during the study, in parallel with decreasing COVID-19 incidences, increasing vaccination coverage of CCWs and parents, and decreasing perceived threat posed by the pandemic. If the objective is to exclude COVID-19 introduction to DCCs with a probability of at least 95%, continuous testing in DCCs should be started at an age-adjusted incidence rate between 50 and 200 per 100,000.
Forster et al. (2022)	In this non-randomised controlled trial, surveillance for COVID-19 in 9 German daycare centres was feasible and well accepted. Mathematical modelling estimated that testing can minimise the spread of COVID-19 in daycare centres.
Fougère et al. (2021)	While RT-PCR testing on saliva performed more poorly in younger children and likely after a longer duration of symptoms, saliva remains an attractive alternative to NPS in children.
Hurst et al. (2021)	Hispanic ethnicity and a sibling with COVID-19 infection increased risk among children, while asthma is associated with a decreased risk. Age-related differences in clinical manifestations of COVID-19 infection must be considered when evaluating children for COVID- 2019 and in developing screening strategies for schools and childcare settings.
Kumar et al. (2022)	While neonates with a positive screen at admission had higher odds of contracting COVID-19, the sensitivity was poor (43% of confirmed COVID-19 cases had a negative screen). These observations support a universal testing screening policy. The practice of universal testing of all outborn neonates requiring admission was not based on neonatal data but rather an extrapolation from older age groups. This study provides some evidence for this practice, although the sample sizes are not large enough to make conclusive recommendations.
Lee et al. (2023)	This study demonstrated that saliva-based COVID-19 testing with young children, parents, and teachers at ECE sites is generally well received and may serve as an additional layer of protection to ensure children's safe return to ECE in the wake of the pandemic. Alternative strategies may be needed for younger children (0–3 years) to participate in ECE site-based COVID-19 screening.
Moraleda et al. (2022)	RT-PCR on the OSS sample is an accurate option for COVID-19 testing in children. A less intrusive technique for younger patients, who usually are tested frequently, might increase the number of patients tested. Saliva swabs may be more acceptable for younger patients than a nasopharyngeal swab, possibly increasing the testing capacity for this age group.
Olivar-López et al. (2020)	Infants and adolescents with sudden onset of symptoms (chest pain for children who can report it) and a history of contact with a confirmed COVID-19 patient may be the primary factors to be screened with testing.

Author (Year)	Recommendations
Oliver et al. (2021)	In children over 10 years of age and adults, saliva testing alone may be suitable for COVID-19 detection, while for children under 10, saliva testing may be suitable as an adjunct to oropharyngeal nasal swab testing for increasing case detection.
Weng et al. (2021)	In all ages, exposure history most accurately predicted infection. Anosmia or ageusia is highly specific in children over 5 years old and dyspnoea in children 5–11 years old and should raise providers' index of suspicion for COVID-19; however, the sensitivity of this symptom is low. The overall findings underscore the limited diagnostic value of symptoms and the critical need for widely available, efficient testing.
Westbrook et al. (2022)	With high Delta variant prevalence, children with isolated symptoms were as likely as those with multiple symptoms to test positive for COVID-19. Isolated fever, cough, sore throat, or headache, but not congestion/rhinorrhoea, offered the highest predictive value. These findings suggest that school and daycare policies should consider isolated symptoms as potential triggers for exclusion and testing.
G. Y. Zhou et al. (2022)	The presence of most symptoms did not meaningfully increase the likelihood of testing COVID-19 positive, especially in children with no known COVID-19 exposure. This suggests that a more limited symptom list could be used as the pandemic continues to evolve to create more parsimonious symptom criteria for exclusion and testing. Excluding students or staff with nonspecific symptoms was unlikely to identify children effectively or efficiently with COVID-19 and likely contributed to unnecessary learning loss. The use of LRs and numbers needed to screen demonstrated that excluding and testing 5–18-year-olds with loss of taste or smell and those of all ages with exposure to COVID-19 would have been reasonable approaches to identify COVID-19 cases during the study period.

Note. PCR = Polymerase chain reaction; RT-PCR = Reverse transcription polymerase chain reaction; LR = Likelihood ratio; RAgT or AgRDT = Rapid antigen test; OSS = Oral saliva swab; NPS = Nasopharyngeal swab; DCC = Daycare centre; CCW = Childcare worker; ECE = Early childcare centre.

Limitations

All of the included studies had some limitations, as summarised in Table 8. Some limitations include Chiwandire et al. (2023), who used nationwide databases to recall data; however, different COVID-19 testing recommendations throughout geographical locations and differences between public and private hospitals may have accounted for differences in COVID-19 recorded cases. Also, data was only recorded for people who presented for healthcare, without knowing how many positive COVID-19 people were not diagnosed (Chiwandire et al., 2023). Cohen et al. (2020) suggested that as an NPS collection in younger children can be difficult, this could have affected the low positivity rates of COVID-19 in their study. Engels et al. (2022) performed their study in the same childcare centres after Forster et al. (2022) conducted their study at a time of low COVID-19 incidence, which could have affected the findings in both studies. Saliva sampling was unavailable for those under 2 years of age in both of these studies, and both studies did not have any control over at-home sampling (Engels et al., 2022; Forster et al., 2022). Engels et al. (2022) allowed parents to select the type of surveillance testing they wished to participate in, and Forster et al. (2022) could not avoid clustering households or childcare centres into groups. Fougère et al. (2021) had only 31/397 children in their study who were under the age of 6, and with this younger age group finding drooling difficult, this may have affected the ability to evaluate findings. The criteria for COVID-19 testing were selective in this study and differed between those under 12 years and those over 12 years (Fougère et al., 2021). While they did perform their research at a time of higher incidence of COVID-19, they excluded all hospitalised and asymptomatic children, potentially affecting their findings (Fougère et al., 2021). Hurst et al. (2021) followed local guidelines for COVID-19 testing which changed during their study, and the testing availability may have limited participant recruitment. In their study, some samples were taken at home, so they were not controlled by the researchers, and the findings were not easy to examine as they were not all broken down by age (Hurst et al., 2021). Lee et al. (2023) had only 6 children under 3 years of age in their study, recruited via volunteers with a priority on Hispanic families. The parents reported their child's ability to produce a saliva sample, so the researchers did not control this (Lee et al., 2023). Moraleda et al. (2022) only included symptomatic patients and did not have centralised testing, meaning there may have been some discrepancies in COVID-19 test results. They conducted their study during the Alpha wave of COVID-19 and felt it may not be replicable in consequent COVID-19 waves (Moraleda et al., 2022). Olivar-López et al. (2020) assessed symptoms in under 2-year-olds differently to those in over 2-year-olds, which was likely to result in some discrepancies in symptomology findings. Oliver et al. (2021) prioritised children positive for COVID-19 or close contacts of infected people, potentially biasing the findings. They found 9% of their saliva samples unable to be processed, and a different saliva collection method was used in children under 5 years of age to those over 5, as well as work not being synchronised between sites and therefore potentially introducing further bias (Oliver et al., 2021). Weng et al. (2021) did not evaluate all symptoms in the under 5-year-olds, and those reported were self-reported, leading to some variation in symptomology. They also suggested that their study was performed early in the pandemic, and subsequent COVID-19 variants may give rise to changes in

symptomology (Weng et al., 2021). Westbrook et al. (2022) only included 112/602 under 5-year-old participants, which limited the ability to detect significant differences in this age group. They also did not collect data on symptom severity, viral loads, or asymptomatic testing. While there was a lower prevalence of COVID-19 in those under 4 years of age in their geographical region at the time of testing, the circulation of other respiratory viruses may have impacted their symptomology reporting and incidence of COVID-19 (Westbrook et al., 2022). G. Y. Zhou et al. (2022) excluded participants with incomplete symptom screening; however, they also had variations between data collected at different sites. Their symptomology may be further biased by the challenge of assessing a younger child and the variation of assessors, including the self-reporting of COVID-19 contact (G. Y. Zhou et al., 2022).

Table 8

Limitations of Included Studies

Author (Year)	Limitations
Chiwandire et al. (2023)	Differing testing strategies and recommendations for testing during the timeframe and throughout different regions and differences between private and public hospitals may account for less data accuracy. The study relied on people presenting themselves for healthcare; consequently, there will be some variability in data. Some health data was missing from records, and data on deaths was only captured for hospitalisations, which could have biased the results.
Cohen et al. (2020)	Difficulty in collecting NPS samples from younger children could affect the low positivity of COVID-19 in study results. Due to mandated lockdowns, household transmission may have been overestimated in this study, as positive serology was noted in the study to be similar to rates in hospitalised and school children.
Engels et al. (2022)	A previous study was conducted on COVID-19 testing in these same childcare centres, and participation rates varied among centres, which could lead to some bias. Childcare centres were pre-selected and non-randomly, and parents were able to volunteer to participate and self-select the group for testing methods. The study was conducted during a period of low incidence of COVID-19 and higher vaccination rates, which could also affect participation rates. The study excluded children under 2 years, and home-based testing and documentation of these results could not be controlled. Self-sampling methods were not evaluated for test effectiveness.
Forster et al. (2022)	This study only included one city at a time when COVID-19 variants were less transmissible. They used a non-randomised design. Children under 2 years of age were not assessed by saliva sampling, and at-home saliva sampling could not be monitored. Dropout rates varied amongst the groups. The study could not avoid clustering households and childcare centres in groups.
Fougère et al. (2021)	COVID-19 testing in this study was according to criteria, and this was more restrictive for those under 12 years of age. Only 31/397 children were under 6 years of age, and many could not drool for a saliva test, affecting the ability to evaluate findings in the under 6-year-olds and limiting the ability to detect differences in age and duration of symptoms. This study was performed at a high prevalence period of COVID-19, which may affect positive predictive values. Hospitalised or asymptomatic children were excluded, which may affect the generalizability of findings.
Hurst et al. (2021)	Testing for COVID-19 in the study was limited by local guidelines, which broadened during the study, from testing symptomatic people to testing symptomatic as well as people who had a close contact with COVID-19, and also to include different ethnicities. The study did not identify transmission settings for COVID-19. Testing availability may also have limited recruitment. Sample recruitment may be biased by including positive children, as the total number of contacts in the area is unknown. Children were only sampled at one point, so not all COVID-19 positive cases may have been correctly identified. Symptomology is difficult in children under 5 years of age due to their inability to articulate. Sampling techniques may differ as some samples were collected at home. Results were not all broken down by age, so it was difficult to draw conclusions for the younger age group.
Kumar et al. (2022)	COVID-19 testing of neonates changed during the study from selective to universal testing, based on adult data. Data collection for COVID-19 negative neonates was not recorded, CT was only done for 2 neonates, and contact tracing was not performed for all neonates, which may limit analysis. Formal sample size was not calculated as it was a retrospective study. The study only included outborn neonates and findings may be different for inborn neonates. COVID-19 test results were known at inclusion point, and neonates who were not tested were excluded.

Author (Year)	Limitations
Lee et al. (2023)	Smaller sample size of younger children (only 6 children under 3 years), parents reported on the children's ability to produce the sample allows some variability, and using volunteers allows some sample bias. Prioritising Hispanic families with young children also introduces some bias. COVID-19 test results were not able to be linked with surveyed information for privacy reasons.
Moraleda et al. (2022)	This study was performed during the Alpha wave, so may not replicate to all variants of COVID-19. Only included symptomatic participants. Reinfection was not addressed, and not all discordant results had serology results available. Non-centralised testing could have led to some discrepancies in test results. The study had presumed consecutive enrolment as this was not stated.
Olivar-López et al. (2020)	Modes of transmission could not be assessed due to unavailable data for all children. Children under 2 years of age were assessed for irritability, children over 5 years of age were assessed for headache, abdominal pain, chest pain, arthralgias, myalgias, which may result in some assessment discrepancies.
Oliver et al. (2021)	The study prioritised close contacts and those with known COVID-19 to participate, which may have biased study. Only 12% of participants were under 5 years old. They found 9% of saliva samples unable to be processed, often due to inadequate volume of saliva, and this may have skewed results to more positives in the OPS. Work was not synchronised between sites, and in the hospital setting, a different saliva collection method was used for children under 5 years of age than for children over 5 years, which could impact the comparability of results in children under 5 years of age between sites. The study assumed all COVID-19 positive results were true, not allowing for any false positives.
Weng et al. (2021)	Some symptoms were not evaluated in under 5-year-olds in this study due to their inability to articulate. Data was collected early in the pandemic, so symptoms could vary between variants. Time from symptom onset to test was missing for many participants. Symptoms were self-reported and could lead to some interpretation bias.
Westbrook et al. (2022)	Did not collect data on severity of symptoms, or why asymptomatic children were being tested. Lower prevalence of COVID-19 in region in under 4 years of age at time of testing and small sample size (*N* = 602, including 112 children under 5 years of age) limited the numbers for each symptom and, therefore, analysis, as well as ability to detect significant differences in under 5-year-olds. Different PCR assays used for samples, so viral loads unable to be gathered, and variant of COVID-19 was not tested for. Few children were vaccinated, so they could not analyse this. The circulation of other respiratory viruses at the time may have impacted predictive symptomology and positive rates.
G. Y. Zhou et al. (2022)	This study had some variations across the three collection sites and excluded all participants with incomplete symptom screening and all asymptomatic school screening. Site 3 had all participants with less than five symptoms marked present or absent excluded. Symptomology assessment is more challenging in younger preschool children as parental or school screening will also vary due to different assessors. Exposure to COVID-19 was not clearly defined at sites and could vary the accuracy of data. The likelihood ratio for less common symptoms may have been harder to detect in this sample. Close contact to COVID-19 was self-reported only.

Note. PCR = Polymerase chain reaction; OPS = Oropharyngeal Swab.

Discussion

The 14 studies included in this review provided pertinent data to answer the research question (Chiwandire et al., 2023; Cohen et al., 2020; Engels et al., 2022; Forster et al., 2022; Fougère et al., 2021; Hurst et al., 2021; Kumar et al., 2022; Lee et al., 2023; Moraleda et al., 2022; Olivar-López et al., 2020; Oliver et al., 2021; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). Seven studies reviewed the use of symptomology to diagnose COVID-19, and while the authors agreed on the common symptoms of children under 6 years of age, they concluded that symptomology alone was not a reliable diagnostic tool (Cohen et al., 2020; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). The additional evaluation of efficacy, acceptability, and viral loads was useful, but each test had its own merits and limitations (Chiwandire et al., 2023; Cohen et al., 2020; Engels et al., 2022; Forster et al., 2022; Fougère et al., 2021; Hurst et al., 2021; Kumar et al., 2022; Lee et al., 2023; Moraleda et al., 2022; Olivar-López et al., 2020; Oliver et al., 2021; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). Understanding vulnerability (comorbidities, age, COVID-19 contact, social determinants of health) and health outcomes of children under 6 years of age also assisted COVID-19 diagnosis (Chiwandire et al., 2023; Cohen et al., 2020; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022).

Symptomology

This review included seven studies that reported on symptomology in under 6-year-olds (Cohen et al., 2020; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). The most reported symptoms included fever or respiratory symptoms (cough, dyspnoea, or coryza). Less frequently, but also reported symptoms included headache, myalgia, gastrointestinal symptoms, sore throats/pharyngitis, nasal congestion, abdominal pain, muscle aches, conjunctivitis, rash, fatigue, chest pain, irritability, and loss of taste or smell (Cohen et al., 2020; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022).

Similarly, Cui et al. (2021) critically reviewed 48 studies of children under 6 years of age with COVID-19, where at diagnosis, fever was present in 51% of children, cough in 41%, sore throat in 16%, tachycardia in 12%, rhinorrhoea in 14%, nasal congestion in 17%, tachypnoea in 9%, diarrhoea in 8%, vomiting in 7%, hypoxemia in 3% and chest pain in 3% of children. Cui et al. (2021) reported that children under 1 year of age experienced fever (53%), cough (30%), rhinorrhoea (21%), nasal congestion (50%), tachypnoea (33%), and vomiting (33%) (Cui et al., 2021). Liguoro et al. (2020) further reported that children aged 1 month to 18 years experienced fever (51. 6%), cough (47. 3%), sore throat (17. 9%), dyspnoea (7.7%), diarrhoea (9.7%), vomiting (7.2%), and fatigue (10.6%). Dyspnoea was the most commonly reported symptom in neonates (0–6 weeks) (40%), followed by feeding intolerance (24%) (Liguoro et al., 2020). In a small study evaluating febrile illness in

infants under 57 days of age, the authors found that infants with poor feeding or lethargy were more likely to be COVID-19 positive (Leibowitz et al., 2021).

COVID-19 has been frequently reported to be a mild illness in children, with the most common presenting symptoms being fever, cough, headache, diarrhoea, and a sore throat in children under 9 years of age (Shane et al., 2020). Lazzerini et al. (2021) reported that fever was highly prevalent in COVID-19 positive children, which was also reported in Kumar et al.'s (2022) study with neonates. Lazzerini et al. (2021) reported respiratory (dry cough) and neurological symptoms (muscle or joint pains) were frequently reported, and respiratory (sore throat) and gastrointestinal symptoms (nausea) were less frequently reported in COVID-19 positive children (Lazzerini et al., 2021). In a study by Ferrari et al. (2022), nasal symptoms were most frequently reported by COVID-19 negative children and fever and gastrointestinal symptoms were more commonly reported in confirmed COVID-19 cases for children under 4 years of age. Similarly, Tchidjou et al. (2022) reported fever, rhinitis, and cough were the most common symptoms experienced by children with COVID-19 in Europe, whereas other less common symptoms included gastrointestinal and neurological symptoms. In China, for children under 1 year of age with COVID-19, similar findings in symptoms were that fever, cough and vomiting were most prevalent (Liu et al., 2020). Zhu and Ang (2022) stated that symptomatology in children was influenced by the child's age, with children older than 10 years more likely to have symptoms in line with adults. Hurst et al. (2021) reported that children, on average, experience symptoms for a shorter duration (*M* = 4 days) than older-aged children. Of interest, G. Y. Zhou et al. (2022) found that symptomatology in all age groups did not have a strong positive likelihood of association with COVID-19. Westbrook et al. (2022) also stated that the number of presenting symptoms was unlikely to predict a positive COVID-19 test in children (Westbrook et al., 2022).

With the broad spectrum of COVID-19 symptoms in children, detecting and diagnosing the virus is challenging (Chang et al., 2020; Poline et al., 2021). Poline et al. (2021) evaluated how many children were admitted to a French hospital and tested positive for COVID-19 based on presenting symptoms. Forty-two percent of children had symptoms suggestive of COVID-19, and the most frequent symptoms were fever, diarrhoea, vomiting, abdominal pain, upper respiratory infections, and skin rashes. While children were assessed on their symptoms, Poline et al. (2021) found that symptom screening was ineffective in positive identification of cases, as 45% of positive COVID-19 cases were asymptomatic (Poline et al., 2021).

Chung et al. (2021) discovered that children were less likely to present with symptoms compared to adults and that children under 6 years of age were less able or likely to explain their symptoms due to developmental and cognitive capacity. While it is appropriate to assess findings such as fever or respiratory distress in neonates (Kumar et al., 2022), attention needs to be given to the developmental stage of a child, as some studies did not assess all symptoms in under 6-year-olds such as a loss of smell or taste (Olivar-López et al., 2020). While loss of taste or smell is not one of the more frequent symptoms in children, it appears to be one of the strongest predictors of COVID-19 (Nikolopoulou & Maltezou, 2022).

A thorough history in symptomatology collection is not new to the medical or nursing discipline, as noted by Hampton et al. (1975). Hampton et al. (1975) note that a medical history, physical examination, and laboratory investigations form the basis of the diagnosis. Viral infections have a varied clinical presentation; therefore, it is vital that the medical and nursing team assessing children have a clear understanding of clinical manifestations, epidemiology, current variants, symptomatology, and transmissions of common viruses, including COVID-19 (Alter et al., 2015). Symptomatology and illness progression are critical to inform a correct diagnosis (Alter et al., 2015; Zhu & Ang, 2022). It is reported that differentiation of COVID-19 from other respiratory viruses is not always easy due to the similarities in symptoms (Poline et al., 2021). A careful medical and nursing history and analysis of symptoms are necessary, as well as the use of appropriate child-friendly effective COVID-19 diagnostic tools (Wawryk-Gawda et al., 2021).

A comparison of the identification and screening for other respiratory viruses, especially RSV in children, is useful in directing actual to potential inferential COVID-19 diagnosis. Movva et al. (2022) undertook a review evaluating the testing patterns, frequency, and incidence of testing for RSV in children; they discovered that the clinical decision to test for RSV was not always clear (Movva et al., 2022). Current trends still favour a PCR test for diagnosis, but overall, a lack of routine testing was reported as high (Movva et al., 2022). Jung et al. (2021) reported that a cheap and reliable test is needed in diagnosing respiratory viruses in children as RSV and influenza affect many children worldwide (Jung et al., 2021). Data from an NZ study suggested that a clinical diagnosis on the sole basis of a case definition or single symptom is not useful in diagnosing influenza or RSV unless followed up with diagnostic testing (Davis et al., 2022). In a study undertaken in Sierra Leone, it was evident that other illnesses, such as malaria (4 children) and an abscess (1 child), made the diagnosis of COVID-19 problematic in a study that included 9 children (Adetola et al., 2020).

Early symptoms of COVID-19 in children can be nonspecific and overlap with other pathogens (Cai et al., 2020). In a study undertaken in China, out of 97 probable cases, 13 were confirmed COVID-19 positive, 41 had another pathogen as their cause of illness, and 43 had no pathogen identified (Cai et al., 2020). Similarly, in Iran, 474,761 children under 19 years of age were symptom screened for COVID-19 (Shayganmehr et al., 2021). After screening, 680/474,761 were considered suspected, and 230 of these were probable cases, yet only 15/230 confirmed COVID-19 positive on PCR (Shayganmehr et al., 2021).

Weng et al. (2021) suggested that a COVID-19 diagnosis based on symptoms alone is of limited diagnostic value, but history of exposure is the most influential factor in predicting a positive COVID-19 test. They suggested that different age groups need distinct symptom screening criteria, as symptoms vary in frequency between ages. For example, in under 6-year-olds, fever and cough were the most frequent symptoms. Children without fever or a positive COVID-19 contact were less likely in the context of a respiratory illness to test positive for COVID-19 (Roversi et al., 2022). This study found 99.3% of symptomatic children without exposure or fever to be negative when tested for COVID-19 (Roversi et al., 2022).

Smit et al. (2022) also found that symptomatic screening for COVID-19 was not entirely dependable. They tested 196 children for COVID-19 in a 2-week period, where approximately half of these children were symptomatic with either acute respiratory, fever, or gastrointestinal symptoms. Of the 11 positive tests, only 1 was symptomatic (Smit et al., 2022). In another study, for 1,459 paediatric patients tested via an asymptomatic protocol in an emergency department setting, 29 tested positive for COVID-19 and with further assessment, 14 were symptomatic, meaning the remainder (*n* = 15) were asymptomatic (Ford et al., 2022). In a study by Snowden and Patwardhan (2021), the majority of children with COVID-19 presented as asymptomatic (62.4%). Of interest, Leung et al. (2023) measured the prevalence of symptoms between COVID-19 variants in children and concluded that due to variation in predominant symptoms, screening on symptoms alone reduced the effectiveness of COVID-19 diagnosis.

Diagnostic Tests

The most commonly used diagnostic test utilised in the reviewed studies for the detection of COVID-19 was a PCR by either an oropharyngeal or nasopharyngeal sample (Chiwandire et al., 2023; Cohen et al., 2020; Forster et al., 2022; Fougère et al., 2021; Hurst et al., 2021; Kumar et al., 2022; Moraleda et al., 2022; Olivar-López et al., 2020; Oliver et al., 2021; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). The wider literature reports that gold standard diagnostic testing for COVID-19 is a PCR test of an upper respiratory specimen, preferably by NPS (Shane et al., 2020). Rodrigues et al. (2021) evaluated the effectiveness of nasopharyngeal aspirates versus NPS in Portugal and reported that a nasopharyngeal aspirate is more sensitive than an NPS. Eleven children (12.9%) in their study would have been misdiagnosed if only an NPS were used; of 20/34 under 1-year olds who had a positive aspirate for COVID-19, only 12/34 had a positive NPS (Rodrigues et al., 2021). In under 5-year-olds, 41/75 had a positive aspirate and only 19/75 had a positive NPS for COVID-19. The authors state that an aspirate specimen may be impractical for outpatient settings and further acknowledge that sputum, saliva, nasal and mid-turbinate swabs are difficult to collect from younger children. However, within a hospital setting, an aspirate may be a realistic viable option (Rodrigues et al., 2021). Of interest within this review, saliva testing either by self-sampled mouth rinsing fluids (drooling saliva) or an oral saliva swab was the next most predominant diagnostic test used in six studies (Engels et al., 2022; Forster et al., 2022; Fougère et al., 2021; Lee et al., 2023; Moraleda et al., 2022; Oliver et al., 2021). RATs were only utilised in three studies (Chiwandire et al., 2023; Engels et al., 2022; Moraleda et al., 2022), as was blood serology via fingerprick blood test (Cohen et al., 2020; Engels et al., 2022; Forster et al., 2022). While RATs were recommended for use in primary care, an NPS PCR was still the gold standard test recommended for a definitive COVID-19 diagnosis, and serology only as a complementary test (Wawryk-Gawda et al., 2021).

Liguoro et al. (2020) state that consideration for testing should be given to the timing of the test as viral load decreases from the initial day of symptoms, lending to children presenting with an asymptomatic mild course of disease missing the diagnostic window (Liguoro et al., 2020). Another important consideration when

utilising diagnostic tests with children is the specificities, sensitivities, appropriateness (age, capacity, developmental level) and cognisance that COVID-19 in children may co-exist with other respiratory viruses or comorbidities (Shane et al., 2020).

Lodi et al. (2021) concluded that healthcare workers versus caregivers had similar accuracy rates in taking nasal sample swabs from children for COVID-19 testing. Lodi et al. (2021) stated that nasal swabs taken at home by parents were less stressful, more accessible to family, and cheaper than a healthcare appointment (Lodi et al., 2021). The pain of nasal swabs, whether anticipated or real, is of great concern to children and parents (Gierszewski et al., 2022). ANSs have been recommended by Harwood et al. (2022) for this reason. Forster et al. (2022) found saliva testing more acceptable to parents and children because of the perceived pain rating of a nasal swab, which was further supported by Virji et al. (2021). Informed parental consent and assent from the child in allowing a swab to be taken, as well as ensuring a child-friendly environment, well-prepared child, health literacy, information sharing, collaboration, partnership, and respect of the child, are areas within COVID-19 testing programmes that require significant consideration (Purssell & Sagoo, 2023). In addition, it has been reported that social determinants of health impact parental and child engagement with COVID-19 testing, vaccinations, and healthcare services (Whitehead et al., 2022). In the García-Vera et al. (2022) study, the lowest income groups often had incomplete data sets and could not be contacted for follow-up on healthcare status for COVID-19.

Some families personally informed me that they chose to purchase their own COVID-19 testing kits rather than use the free ones provided at testing stations, as they perceived them to be easier to use or more child-friendly than a RAT supplied. Other families reported to me that they had been verbally informed they needed to have a negative RAT every day their child attended preschool, despite no apparent guidelines to this effect in NZ. The lack of universal evidence-based guidelines over COVID-19 testing in younger children led to advice being given to the public through social media, healthcare professionals, and news reports (Jeffs et al., 2021). Of interest, Jeffs et al. (2021) reported that parents with the highest fear scores in relation to their child contracting COVID-19 were more likely to trust social media sources over medical or government advice for COVID-19 (Jeffs et al., 2021). Some of this advice was personally witnessed at RAT collection stations in NZ in early 2022 and was given by staff who worked in entirely different disciplines with little official supervision or guidelines.

Efficacy and Acceptability of Testing

In the included studies, Oliver et al. (2021) and Fougère et al. (2021) agreed that an NPS PCR was more sensitive to COVID-19 detection in children than a saliva sample (Fougère et al., 2021; Oliver et al., 2021). Of interest, Moraleda et al. (2022) report that an NPS and saliva sample are similar when a PCR test is performed, but a RAT test in a child under 6 years of age has a poorer detection rate (Moraleda et al., 2022). In addition, Moraleda et al. (2022) reported a lower sensitivity in children under 3 years of age for RATs (Moraleda et al., 2022). However, Ferrari et al. (2022) found RATs to be useful in speed of test result and ease of interpretation,

with limited skills required to perform the test. In their study, only 4.2% (89/2133) of RATs were COVID-19 positive, with a specificity of less than 50% when compared to a PCR test (Ferrari et al., 2022). In a study conducted by Euser et al. (2021), viral load was measured by cycle threshold (CT) levels in children under 12 years of age, where children had a lower viral load based on age. The authors concluded that a RAT test could, therefore, be less sensitive in this age range (Euser et al., 2021). Of interest, Carbonell-Sahuquillo et al. (2021) also evaluated RAT tests in children, finding that the RAT test was less reliable the higher the CT value.

Interestingly, Borrelli et al. (2021) do not recommend a RAT alone for frontline diagnosis. For a RAT to be sensitive and specific, it needs to have a concentration of analyte that will detect 95% of tests (Buchan et al., 2020). Authors from various studies state that specificity and sensitivity in a RAT are consistently lower than in a PCR test (Jung et al., 2021; Mboma et al., 2021; Moraleda et al., 2022). However, it is important to note that this depends on CT values and the day since the symptom onset (Mboma et al., 2021). The sensitivity of the RAT can be improved by using an appropriate swab size, taking a good clinical history, efficient sampling, and ensuring the manufacturer's instructions are followed (Mboma et al., 2021).

In their study, Denina et al. (2022) reported an overall sensitivity of 94.1% and specificity of 91.9% for RATs and recommended a preliminary RAT diagnosis as useful to reduce wait times for further testing. In contrast, Ollier et al. (2022) reported a sensitivity of 82.9% and specificity of 99.8% in symptomatic children, whereas in asymptomatic children, a sensitivity of 27.3% and specificity of 100% were reported. Shaikh et al. (2021) found that children under 7 years of age had a sensitivity of 100% and specificity of 92% for a RAT when using a mid-turbinate swab on symptomatic children, whereas Villaverde et al. (2021) reported that 77 out of 1,620 children who tested COVID-19 positive by PCR from seven hospitals in Spain, only 38/77 tested positive by a RAT (Villaverde et al., 2021).

Sivanandan et al. (2020) recommended a naso-oropharyngeal swab or tracheal sample for a PCR test in neonates and, if negative in symptomatic neonates, to repeat testing in 24–48 hours. While RATs may be indicated as a triage tool, they suggest that a PCR be used for conclusive diagnosis testing in any symptomatic neonate or any neonate with a history of COVID-19 exposure (Sivanandan et al., 2020). Also, in neonates, Kumar et al. (2022) found that a universal testing policy using a PCR nasopharyngeal swab improved COVID-19 diagnosis as opposed to a selective testing protocol in which screening criteria had to be met.

Overall, studies have conclusively shown saliva to be a less sensitive test than nasal PCR or RATs (Fougère et al., 2021; Oliver et al., 2021). However, Moraleda et al. (2022) reported that an oral saliva swab was similar in diagnostic performance to an NPS PCR and attributed this to children under 6 years of age being unable to adequately perform a drool saliva test (Moraleda et al., 2022). While children and parents reported saliva swabs or drool saliva tests to be less invasive, collecting saliva samples from under 3-year-olds was problematic as oral swabs needed to be present for up to 1 minute in a child's mouth (von Linstow et al.,

2021). While there are certainly some benefits, such as the comfort to the patient and less likely lower respiratory droplet contamination, the lower reported sensitivities have led researchers to question OSS as an accurate, reliable test (von Linstow et al., 2021).

Clifford and Curtis (2021) agree that the collection of NPS or aspirates is uncomfortable for children and also has an infection control risk for health care professionals. Their review suggested that the sensitivity of saliva was less than that of a respiratory sample, but that saliva tests reduced time and cost. In addition, the age of the child, days from symptoms onset, and collection methods all impact COVID-19 test sensitivity (Clifford & Curtis, 2021). Fougère et al. (2021) suggested limited diagnostic performance in the under 6-year-old age range, especially when symptom duration was longer than 4 days, as younger children were frequently unable to drool for saliva tests. Few studies have been performed on saliva testing in infants and pre-schoolers, and collection difficulties may be a reason for this. In addition, serology testing together with PCR testing could aid diagnosis to help understand the level of contagiousness (Cohen et al., 2020); however, serological testing is not reliable for indicating current acute disease (Zhu & Ang, 2022). It is important to note that COVID-19 testing in children under 6 years of age needs to be considered with a clinical history and current epidemiology (Denina et al., 2022).

Studies have been undertaken on faecal and anal swabs for COVID-19; however, these studies had fewer participants, and children were usually under 10 years of age (Dona et al., 2020). COVID-19 can be detected from faecal specimens and environmental samples from toilet bowls and sinks (Xing et al., 2020). It is possible that faecal or anal swabs could detect COVID-19 for longer than a respiratory sample suggesting gastrointestinal viral excretion occurs longer than an acute infection (Dona et al., 2020; Xing et al., 2020; Xu et al., 2020). Shao et al. (2021) discovered that children with gastrointestinal symptoms had a longer period of viral shedding and, therefore, tested positive for COVID-19 on PCR testing. While wastewater testing has been performed in NZ, anal swabs have not been commonly used, and further research is required in this area.

As well as testing efficacy, acceptance of COVID-19 testing was evaluated in three studies (Engels et al., 2022; Forster et al., 2022; Lee et al., 2023). Forster et al. (2022) and Engels et al. (2022) both concluded in a continuous surveillance testing situation that parents and children were more accepting of saliva testing compared to mid-turbinate nasal swabbing. Not surprisingly, lower-frequency nasal swabbing was more acceptable than higher-frequency nasal swabbing (Engels et al., 2022), and symptomatic swabbing created more anxiety than surveillance swabbing (Forster et al., 2022). Lee et al. (2023) found that the 4- to 5-year-old children were more likely to report a saliva test as ‘easy’ and were willing to repeat it than the younger children.

Parental attitudes to COVID-19 testing and diagnosis in children is important to consider (Forster et al., 2022; Lee et al., 2023). In a study looking at parents’ and childcare workers’ perspectives towards COVID-19 testing,

parents felt that having a younger child was a barrier to the feasibility and acceptability of testing, especially saliva testing (Gierszewski et al., 2022) with nasal swabs being perceived as more invasive (Forster et al., 2022; Gierszewski et al., 2022). A child-friendly environment in support of parents was an essential consideration in the Gierszewski et al. (2022) study undertaken in German preschools. Gierszewski et al. reported that some caregivers may not be motivated to test their child for COVID-19 as coryzal symptoms in children are common, especially in children attending childcare facilities (Lee et al., 2023). Children themselves also have variable COVID-19 testing experiences, as was evident in the study undertaken by Kaufman et al. (2023), where children exhibited fear and refusal to test. Kaufman et al. (2023) reported that parents found healthcare messages difficult to comprehend, parents did not know where to go to get their under 5-year-old tested, information was inconsistent, and the stress and implications of a positive COVID-19 diagnosis were not explained (Kaufman et al., 2023). It goes without saying that children under 6 years old cannot take themselves to a COVID-19 testing centre or perform tests themselves; therefore, parental perceptions, knowledge, and decisions may influence health care delivery/outcomes and reported incidence/prevalence of COVID-19 in children under 6 years of age.

Viral Loads

The viral load in COVID-19 detection tests can differ in studies when the number of symptomatic and asymptomatic participants in the study group varies and may possibly account for different findings in viral load (Chung et al., 2021). Fougère et al. (2021) reported that viral loads from saliva were significantly lower than an NPS viral load. Similarly, Yonker et al. (2020) reported a higher viral load on NPS than an oropharyngeal sample in 59 out of 192 children under 5 years of age. Yonker et al. (2020) reported that children carried high virus levels in their upper airways, especially in the initial acute COVID-19 infection, even while displaying nil or mild symptoms. However, no age correlation with viral load was discovered (Yonker et al., 2020). Hurst et al. (2021) also found that COVID-19 nasopharyngeal viral load did not differ by age or presentation of symptoms, which was further relayed in the Buchan et al. (2020) study.

In contrast, Gentile et al. (2022) reported that CT values were significantly lower in children under 2 years of age than in older children, participants who had a sample collected less than 4 days after symptom onset, and those who were asymptomatic. This suggests viral loads are higher for children under 2 years of age, those symptomatic, and those tested in a timely manner from the beginning of symptoms. Euser et al. (2021) also reported that viral load decreased as age increased; that is, a higher viral load (lower CT level) in children under 12 years of age with a decreasing viral load (increased CT level) associated with increasing age.

Health Outcomes

The reported mortality rate due to COVID-19 within the included studies was minimal. Kumar et al.'s (2022) study reported a mortality rate of 5 neonates, 2 of which had lethal congenital abnormalities and 3 due to severe sepsis. Olivar-López et al. (2020) reported that 1 child died and a further 11 children required

mechanical ventilation; Hurst et al. (2021) reported 1 child needed hospitalisation for respiratory distress and treatment. Of interest, infants in South Africa had the highest cumulative hospital admission rates but overall low mortality rates (Chiwandire et al., 2023).

Khoury et al. (2023) concluded that COVID-19 in infants younger than 6-months (*n* = 52) had a mild disease with limited complications. In their study, 23 children infected with COVID-19 presented with a normal physical examination, and 37 patients were hospitalised for observation only. Only 3 were treated with antibiotics which were stopped after negative blood cultures (Khoury et al., 2023). In a global cohort study by Funk et al. (2022), amongst the 3,221 young people (including 1,804 participants under the age of 5 years) who had an active COVID-19 infection, 23% were hospitalised, 3% experienced severe outcomes, and 4 children died. This study identified risk factors for severe COVID-19 health outcomes being aged above 5 years of age, pre-existing comorbidity, or a child that presented to hospital 4–7 days after symptom onset (Funk et al., 2022). In the Garazzino et al. (2020) multi-centre study, 52/66 children under the age of 1 year old were hospitalised, and 24/38 one- to five-year-olds were hospitalised. Underlying comorbidities were present in 33 children with COVID-19, and complications of COVID-19 such as pneumonia, peripheral vascularitis, or severe respiratory illness developed in 33 of the children, 2 of which needed ICU treatment. Ten children had a viral co-infection, and one also had a bacterial co-infection (Garazzino et al., 2020).

Vulnerability/Risk Factors

Many studies in this review and the wider literature reported that the highest risk factor for contracting COVID-19 was contact with a COVID-19 positive person, especially a COVID-19 positive sibling (Cohen et al., 2020; Crea et al., 2021; Hurst et al., 2021; Olivar-López et al., 2020; Weng et al., 2021; G. Y. Zhou et al., 2022). Other studies concur on this vulnerability to COVID-19 when contact is made with a COVID-19 positive person (Liguoro et al., 2020). A familial (family member) positive contact could be identified in 73.3% of COVID-19 positive cases in a study by Liguoro et al. (2020). Snowden and Patwardhan (2021) reported that race and ethnicity were significantly associated with the presence of symptoms at the time of testing, and non-Hispanic white or black children were more likely to be asymptomatic when testing positive for COVID-19 (Snowden & Patwardhan, 2021) which was further supported by Hurst et al. (2021). In this review, existing comorbidities were a significant risk factor identified (Chiwandire et al., 2023; Hurst et al., 2021; Olivar-López et al., 2020), which is supported by wider literature (Lazzarini et al., 2021).

COVID-19 hospital admission rates and severity of illness were higher for children with pre-existing comorbidities (Chiwandire et al., 2023). Shane et al. (2020) reported that underlying health conditions such as chronic respiratory conditions, obesity, or neurodevelopmental conditions were common in hospitalised children with acute COVID-19. In North America, 40 out of 48 children had underlying medical conditions; 18 of these children required mechanical ventilation and overall mortality was 4% (Shane et al., 2020). Drouin et al. (2021) also reported that severe COVID-19 was more likely among children with comorbidities such as chronic lung disease, epilepsy, or neurological disorders. In addition, Hardelid et al. (2022) stated that infants

and children with chronic conditions had the highest COVID-19 related admission rates, where 13 of 346 positive COVID-19 admissions required ICU attendance (Hardelid et al., 2022).

Cui et al. (2021) stated that children aged under 1 year of age were more likely to have a critical illness than those older than 1 year (14% vs 5%) (Cui et al., 2021). Similarly, Drouin et al. (2021) reported that infants under 1 year of age had a higher rate of reported COVID-19 infections than adolescents, pre-schoolers, or school-age children in Canada. Thirty-two cases (21.3%) were admitted to ICU and 9 required mechanical ventilation, with 5 deaths (Drouin et al., 2021). Sivanandan et al. (2020) reported that 38% of neonates required admission to a neonatal unit and 17% required respiratory support. Devin et al. (2022) reported that low birth weight or prematurity in neonates were significant risk factors for severe COVID-19 illness in America (Devin et al., 2022). A total of 71 out of the 918 neonates were deemed to have a severe COVID-19 illness, with 1 death. Neonates with severe COVID-19 were more likely to receive respiratory support and required a larger number of medications as well as a longer stay in hospital (Devin et al., 2022). In addition, Snowden and Patwardhan (2021) reported that children aged over 10 years were more likely to have critical or severe COVID-19 disease than younger children (Snowden & Patwardhan, 2021). Lazzarini et al. (2021) also reported that children between 2 and 9 years of age had a lower risk of contracting COVID-19 compared to 10- to 18-year-olds (Lazzarini et al., 2021).

A noteworthy observation was the effect of co-infections on COVID-19 positive children, with potential resultant severity of disease (Chiwandire et al., 2023). In a study by Choudhary et al. (2022), viral co-infections were identified in 101 under 5-year-old children with COVID-19, which was higher than 5- to 20-year-olds (*n* = 12). Factors associated with severe illness included RSV or bacterial co-infection. Interestingly, in this study, prematurity was not associated with severe illness (Choudhary et al., 2022). Of the 298 patients who were hospitalised for COVID-19 aged under 5 years old, respiratory support was required in 71.3% who had a viral co-infection but only 38.1% who did not (Choudhary et al., 2022).

Recommendations

Both Engels et al. (2022) and Forster et al. (2022) recommended continuous COVID-19 surveillance testing (saliva sampling) in childcare centres as feasible and acceptable to help minimise COVID-19 infection and spread (Engels et al., 2022; Forster et al., 2022). Clifford and Curtis (2021) and Moraleda et al. (2022) also agree that saliva testing may be useful in ongoing surveillance as it is an acceptable form of testing in children. Fougère et al. (2021) stated that although saliva did not perform as well in COVID-19 diagnosis, it remains an attractive alternative for children compared to an NPS. Lee et al. (2023) demonstrated that saliva-based COVID-19 testing in children was well received by children, parents, and preschool teachers, but due to its limitations, children younger than 3 years may still need further testing methods (Lee et al., 2023). In contrast, Oliver et al. (2021) stated that for children over 10 years of age, COVID-19 saliva testing may be suitable, but additional testing, such as an oropharyngeal nasal swab, is needed for children under 10 years of age. In the wider literature, Virji et al. (2021) stated saliva testing to be feasible and acceptable despite

this being less satisfactory to an NPS in the detection of COVID-19 (Clifford & Curtis, 2021; von Linstow et al., 2021). Cohen et al. (2020) was the only study recommending concomitant serology antibody testing with nasopharyngeal PCR testing for COVID-19 to aid in interpreting PCR results. Interestingly, the AAP (2022) disagrees, stating that while serology testing may be able to prove a past infection, it does not help guide an acute diagnosis of COVID-19 (AAP, 2022). Of interest, Chiwandire et al. (2023) recommended that vaccinations be administered to children 5–11 years of age with any underlying illness. Borrelli et al. (2021) speculated that mandatory vaccinations in childhood could provide some protection against other respiratory viruses, including COVID-19, in children under 6 years of age (Borrelli et al., 2021; Marks et al., 2022).

Other studies recommended a universal testing policy for COVID-19, as symptomatic screening alone is a poor diagnostic tool (Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). Wider literature agrees that the diagnosis of COVID-19 in children is challenging due to nonspecific symptoms resembling many other viruses, and therefore, symptomology alone is not enough for diagnosis (Chang et al., 2020; Cui et al., 2021; Fatemi & Coffin, 2021; Ford et al., 2022; Poline et al., 2021). Differences in age-related manifestations of COVID-19 should be understood (Hurst et al., 2021), which is evident in the literature (Drouin et al., 2021; García-Vera et al., 2022) but a history of exposure to COVID-19 proved to be the most accurate predictive value (Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). Exposure to COVID-19 as a positive predictive factor was reported in wider literature (Chang et al., 2020; Roversi et al., 2022).

Limitations

As with all systematic reviews, this study is limited by search terms, selected databases, search strategy methods, inclusion/exclusion criteria (peer-reviewed published empirical studies in English from 2020–2024) and only two researchers (student and supervisor) undertaking the consensus agreements. In addition, no grey literature (secondary analysis, reviews, guidelines, reports) was included, and the majority of studies were undertaken in developed countries. A further limitation of this review was the mixed-age samples evident within the studies. However, the data reviewed and extrapolated for this review only included children under 6-years-old. Despite these limitations, the procedure undertaken was rigorous and followed a systematic process.

Conclusion

Studies that reported on symptomology agreed on the most commonly reported symptoms, which included fever, respiratory, and gastrointestinal symptoms (Cohen et al., 2020; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). These symptoms were not exclusive to COVID-19 in this age range, and other viruses often present with similar symptoms (Cai et al., 2020). This leads to the challenge of diagnosis, as well as the fact that symptomology alone is not

conclusive (Chang et al., 2020; Poline et al., 2021). Common tests utilised NPS PCR, RATs, and oral saliva tests (Fougère et al., 2021; Moraleda et al., 2022; Oliver et al., 2021). An NPS PCR is the most sensitive to COVID-19 detection in children, while RATs and oral saliva tests have a lower sensitivity (Jung et al., 2021; Mboma et al., 2021; Moraleda et al., 2022). According to parents and children, an oral saliva test is the most acceptable form of testing for more frequent tests because it is perceived as less invasive (Engels et al., 2022; Forster et al., 2022). The sensitivity ranges for these diagnostic tests may be due to the detectable viral load (Chung et al., 2021). NPS samples had a higher viral load than a saliva sample (Fougère et al., 2021). Some studies suggest that younger children and symptomatic people have an increased viral load (Euser et al., 2021; Gentile et al., 2022).

Although overall mortality of COVID-19 in under 6-year-olds is minimal (Chiwandire et al., 2023; Khoury et al., 2023; Kumar et al., 2022; Olivar-López et al., 2020), there is still vulnerability after being in contact with a COVID-19 positive person, particularly a family member (Cohen et al., 2020; Crea et al., 2021; Hurst et al., 2021; Olivar-López et al., 2020; Weng et al., 2021; G. Y. Zhou et al., 2022). Existing comorbidities and a younger age were also identified as risk factors (Chiwandire et al., 2023; Cui et al., 2021; Drouin et al., 2021; Shane et al., 2020). A universal testing policy for COVID-19 is recommended above a symptomatic screening for diagnosis (Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). Saliva sampling was recommended especially for ongoing surveillance screening due to its feasibility and acceptability (Engels et al., 2022; Forster et al., 2022; Virji et al., 2021); however, an NPS is still recommended as the most sensitive diagnostic tool available (Fougère et al., 2021; Oliver et al., 2021).

Recommendations for Practice

The previous chapters have reported and discussed the results of the systematic review. Clinical guidelines and cultural considerations concerning clinical practice in NZ are discussed next. This chapter provides brief recommendations for clinical practice based on the systematic review. While these recommendations are aimed primarily at nurses, they may be helpful for any health professional working with children and young people. At the end of the chapter, these recommendations are provided in a bulleted list for quick reference and a short handout is designed for parents (Appendix B) and children (Appendix C).

Clinical Guidelines

A number of expert-led clinical guidelines have been published in response to COVID-19 (American Academy of Pediatrics [AAP], 2022; The Royal Children's Hospital Melbourne [RCH], 2020; SCH, 2023). A summary of these guidelines can be seen in Table 9. The AAP states that clinical guidelines cannot cover all healthcare scenarios as the current COVID-19 variant in circulation can differ from one geographical region to the next; therefore, clinical judgement and knowledge of community transmission and symptomology of the current COVID-19 variant and other respiratory illnesses will be required (AAP, 2022). The SCH clinical guidelines agree that transmissibility and different variants must be considered when caring for children presenting to healthcare facilities with COVID-19 or symptoms of unwellness (SCH, 2023). The RCH in Melbourne guidelines dictate that healthcare professionals need to focus on the child's presenting complaint, especially assessing symptomology such as fever, headache, lethargy, cough, sore throat, coryza, vomiting, diarrhoea, or abdominal pain (RCH, 2020). Risk factors can include the age of neonates, infants, children, or adolescents; comorbidities including obesity or prematurity; exposure to COVID-19; and non-European ethnicity (SCH, 2023). Clinical features can vary and mimic other viral infections such as croup, RSV, or gastroenteritis, especially in those aged under 5 years (SCH, 2023).

Testing when symptomatic or after being exposed to a close contact within 5 days is recommended by the AAP (AAP, 2022). Consideration needs to be made of a recent COVID-19 infection, as while this may show on a PCR test, it is less likely to show on a RAT (AAP, 2022). Therefore, if the infection was within 90 days, a RAT test may be preferable, although reinfection may also occur (AAP, 2022). If a RAT is negative but the child is symptomatic, the suggested process is to repeat the test in 48 hours (AAP, 2022). The AAP does not suggest using oral samples for any RATs, and no at-home RATs have been authorised for use in children under 2 years of age (AAP, 2022). In contrast to the AAP recommendations, SCH recommends a PCR nasopharyngeal swab as the gold standard for diagnosis, but oropharyngeal and anterior nasal swabs (ANS) can be considered, and RATs may be used (SCH, 2022). The RCH (2020) suggests swabbing all symptomatic children with a combined oropharyngeal and deep nasal swab. Swab size should be considered, especially in children under 12 months of age. Contraindications of this include upper airway obstruction such as croup, bleeding disorders, recent

facial trauma, or mucositis. RCH (2020) have information on distraction techniques and make a prudent point that minimising discomfort and preparing the child and parents is paramount (RCH, 2020).

Table 9

Summary of Clinical Guidelines

	Guideline (year)		
	American Academy of Pediatrics (2022)	The Royal Children's Hospital Melbourne (2020)	Starship Child Health (2023)
Testing indications (Symptomatic)	Immediately test patients with symptoms. Symptoms include fever/chills, cough, nasal congestion/coryza, loss of taste/smell, shortness of breath or dyspnoea, body aches, fatigue, headache, sore throat and gastrointestinal symptoms (nausea, vomiting, diarrhoea).	According to current guidelines and case definitions per state.	Common symptoms include fever, cough, nausea/vomiting, diarrhoea, sore throat, abdominal pain, shortness of breath, rhinorrhoea, myalgia, and headache. Omicron can present similar to croup or gastroenteritis.
Testing indications (Asymptomatic)	If asymptomatic but close contact within 5 days of contact. Close contact is defined as a distance less than 6 feet for at least 15 minutes in a 24-hour period.	As above.	As above.
Diagnostic tests recommended	Use either a PCR or RAT. If RAT is negative, retest in 48 hours; if negative again, retest again in 48 hours. Oral samples are not recommended over nasal samples. No at-home antigen tests are recommended for children aged under 2 years.	An oropharyngeal and deep nasal swab. Use a smaller swab on infants under 1 year of age.	An RT-PCR on nasal samples in the first instance. An oropharyngeal and anterior nares sample could be considered. RAT tests may be used.
Other considerations	Vaccination status should not guide decisions. Consider other pathogens such as influenza. Allow clinical judgement.	Due to child discomfort, care should be taken to prepare and minimise distress. Additional information is given on procedure and distraction techniques. There are some contraindications for swabbing, such as facial trauma to consider.	Risk factors include age under 1 month and children 10–18 years, prematurity before 37 weeks, non-European ethnicity, and underlying comorbidities. Consider other pathogens.

Note. RAT = Rapid antigen test; RT-PCR = Reverse transcription polymerase chain reaction.

Cultural Considerations

Te Tiriti o Waitangi underpins the Crown's relationship with Māori (Heke et al., 2019). In relation to health, the NZ Government is obliged to ensure ōritetanga (equitable health outcomes) and tino rangatiratanga (that Māori are resourced to have self-determination) at an individual level; hence, health professionals need to be culturally safe in all practices to align to these founding principles (Heke et al., 2019). Many inconsistencies regarding cultural competence are cited in health practice (Heke et al., 2019). It requires knowledge, skills, and attitudes, with a constant reflection on practice (Heke et al., 2019). This cultural competence is critical to improving outcomes for Māori regarding their health and wellbeing (Heke et al., 2019).

Many Māori whānau still receive sub-optimal care in primary, secondary and tertiary-level healthcare settings as influenced by various factors (Masters-Awatere & Graham, 2019). It is known that delayed or reluctant engagement with primary healthcare providers from Māori exists (Masters-Awatere & Graham, 2019). Research has found that engaging with Māori from a kaupapa Māori orientation, including speaking te reo Māori, was important for better outcomes for whānau (Masters-Awatere & Graham, 2019). Being listened to and having experienced health professionals take their time was important. This would include taking time with COVID-19 testing (Masters-Awatere & Graham, 2019). Perceptions that health staff are too busy can lead to negative connotations and reluctance to engage with services (Masters-Awatere & Graham, 2019). The suggestion that staff need to establish a relationship to focus on the needs of whānau and tamariki (children), rather than the needs of the health professional or clinic deadlines is paramount to ensure positive health outcomes for Māori (Masters-Awatere & Graham, 2019). This could mean the difference between simply taking a nasal swab or taking a history and then answering relevant questions from whānau before any testing. That is the essence of listening (Masters-Awatere & Graham, 2019). In conjunction with this, parent's reluctance to test their child for COVID-19 can be for a range of reasons, such as fear of testing positive (Ciacchini et al., 2020), perceived pain of the test (Gierszewski et al., 2022), or lack of general understanding, which can lead to less testing (Kaufman et al., 2023). If Māori are already receiving sub-optimal care, are reluctant to engage with health services (Masters-Awatere & Graham, 2019), and have a range of general parental concerns (Jeffs et al., 2021; Kaufman et al., 2023), fewer Māori children may be tested for COVID-19, and therefore the balance of healthcare support will remain unequal.

An outstanding example of a kaupapa Māori response to COVID-19 was the Te Whānau o Waipareira Trust (Whānau Ora Commissioning Agency [WOCA], 2021). Initially, a lack of consultation with Māori on the COVID-19 response led to poor vaccination rates (WOCA, 2021). Previous mainstream services are largely ineffective in Māori communities, so taking a proactive role in reaching Māori whānau by using core Māori values that have high levels of service engagement resulted in higher numbers of Māori being tested and vaccinated for COVID-19 (WOCA, 2021). Te Whānau o Waipareira Trust used a model with key components: kaupapa driven, culturally grounded, and whānau centred, having a high trust model with local leadership, and supporting continuous learning and communication (WOCA, 2021). This is a great exemplar of a service provided by

Māori, improving outcomes for Māori whānau and tamariki, that has to date not been made mainstream, hence, failing to meet the health needs of Māori.

The links between ill health and social and economic depravity are well-known, with Māori disproportionately impacted (Heke et al., 2019). A loss of culture through colonisation and racism serves to exacerbate this problem, as well as the impact of the neoliberal governmental stance on health in NZ as a large burden (Barnett & Bagshaw, 2020). The literature states that being non-European (SCH, 2023) or from a low-income group (García-Vera et al., 2022) increases a child's risk factors for being positive for COVID-19. In NZ, being Māori can have further risk factors for ill health and negative outcomes (Heke et al., 2019). This means that good history-taking becomes paramount, as well as shared decision-making, partnership/collaboration, relationship building, and the use of age-appropriate child-friendly COVID-19 testing methods considering the child's developmental level and social capability as well as being cognizant of cultural barriers (Masters-Awatere & Graham, 2019).

Considering best practice is important to achieving the outcome most health professionals want, which is improving the health of children and their whānau. Understanding what we mean by best practice is important as this can incorporate scientific research, professional standards, risk analysis, quality control, and the perspectives of our children and whānau (Carter et al., 2014). Our interpretation of what best practice can encompass may be influenced by our culture, context, beliefs, knowledge, age, and level of clinical experience (Carter et al., 2014). Nurses may often be influenced by their colleagues' practice, what a senior nurse has informed them, or societal norms (Carter et al., 2014). A recommendation for practice that disagrees with the health professional, child, or family's beliefs would be ineffective as it is unlikely to implement change (Carter et al., 2014). We must remember that childhood is a culture (Carter et al., 2014). This might mean that best practice is less of an absolute and more of a spectrum (Carter et al., 2014). It may not be plausible to ask a neonate, infant or pre-schooler if they would like a RAT or nasopharyngeal PCR, but it is best practice to consider their view, as voiced by their whānau (Carter et al., 2014). A child's active involvement in matters that concern them could include their preferences, such as where the child sits, who holds them, or even negotiation over a treat after the test (Carter et al., 2014). Using resources such as Appendix C gives child more information, invites more discussion, and introduces health literacy at a developmentally age-appropriate level.

Where possible, a good history and symptomology from caregivers and children are recommended for diagnosis (Alter et al., 2015; Zhu & Ang, 2022). This should include ethnic and socioeconomic factors and any potential close contacts (Cohen et al., 2020; Üzel et al., 2021). Being from a lower socioeconomic group (García-Vera et al., 2022) or a non-European ethnicity (SCH, 2023) can increase the risk of exposure to COVID-19. Common symptoms are well described and collated by studies but predominantly include fever and respiratory symptoms such as cough, dyspnoea, or coryza (Cohen et al., 2020; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). COVID-

19 in children can present with a wide range of symptoms other than respiratory, including headache, myalgia, gastrointestinal symptoms, sore throats/pharyngitis, nasal congestion, abdominal pain, muscle aches, conjunctivitis, rash, fatigue, chest pain, irritability, and loss of taste or smell (Cohen et al., 2020; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020; Weng et al., 2021; Westbrook et al., 2022; G. Y. Zhou et al., 2022). Variations in symptoms by age and COVID-19 variant strain are possible, but these variations are not always good predictors of a diagnosis of COVID-19 (Weng et al., 2021; G. Y. Zhou et al., 2022). Children may be unwell for a shorter period than adults (Chung et al., 2021; Hurst et al., 2021). Considering other viruses as a differential diagnosis is also important (Cai et al., 2020; Shayganmehr et al., 2021). While children under 6 years of age had low mortality rates, comorbidities or a younger age could increase the risk of severe disease, hospital admission, or death (Chiwandire et al., 2023; Hurst et al., 2021; Kumar et al., 2022; Olivar-López et al., 2020).

Testing via a RAT or PCR will depend on the sample's viral load (Clifford & Curtis, 2021). This means it is preferable to test via these methods closer to the onset of symptoms rather than the during the recovery phase (Fougère et al., 2021). Viral load may not depend on symptom presence or vary by age group (Hurst et al., 2021). Saliva tests appear to be less sensitive than respiratory samples (Fougère et al., 2021), and saliva drool tests or saliva collection is generally impractical on anyone under 6 years of age (Moraleda et al., 2022). However, a saliva swab may be considered if this option is available. A PCR sample is still the most sensitive test over a RAT test (Moraleda et al., 2022); however, RAT tests have the advantage of being cheaper and faster. If a case is time-sensitive, then a RAT would be preferred. If you need the most accurate sample, then an NPS PCR is still the most recommended. Appropriate swab size, testing within the window of higher viral load (as close to the day of onset of symptoms as possible), and following manufacturer instructions will all aid in better sensitivity in the RAT (Mboma et al., 2021). Anal PCR swabs have not been researched in NZ on children. NPS sites are the most widely researched sample sites, but often ANS are used in RATs. SCH clinical guidelines recommend an NPS PCR, or alternatively an oropharyngeal or ANS, as well as RATs (SCH, 2023). The RCH (2020) recommends a combined oropharyngeal and deep nasal swab. AAP (2022) does not recommend any RAT tests on children under 2 years of age. The health professional will know what is available to them in their clinical situation, as well as having the child and whānau in front of them, and therefore will need to choose which form of testing, if any, they think in consultation with the family will be pertinent.

Many families will accept saliva testing over nasal testing (Engels et al., 2022; Forster et al., 2022), and pain or discomfort, even if perceived, may influence a family's decision more than the accuracy of the test. Drool saliva testing has been performed in NZ, but saliva swabs for children under 5 years old are not readily available to the best of my knowledge. Caregivers may wish to take the swab themselves, and the evidence is that they may have a similar accuracy rate to healthcare workers (Lodi et al., 2021). Whānau are concerned about testing their children for COVID-19 (Kaufman et al., 2023). They need to feel listened to, spoken to in

an appropriate language, and be provided opportunities to build honest relationships with healthcare professionals (Masters-Awatere & Graham, 2019). Health professionals will need to assess how to achieve this in their own practice setting. A child-friendly environment and the experience of testing for their child are also important to whānau (Gierszewski et al., 2022), so again, the approach and physical setup of any clinical setting needs to be prepared appropriately.

Recommendations For Health Professionals Quick Guide

This guide was written as an example of a summary reference sheet for health professionals based on this review. In addition, information sheets for parents, caregivers and children have been generated from this review as presented below and in Appendix B and C.

COVID-19 has a range of clinical symptoms in children under 5 years old.

The most common symptoms in this age range are:

- Fever
- Cough
- Nasal congestion/Rhinorrhoea
- Vomiting
- Diarrhoea

However, COVID-19 is a systemic virus, and while respiratory and gastrointestinal symptoms are most common, other symptoms such as irritability, poor oral intake, and skin rashes may also be present. Remember that this age group will not often articulate fatigue, myalgia, sore throats, or loss of smell/taste. Also, remember that different variants can produce some variation in symptoms, so it is important to know the most common geographical symptoms.

A history of a household member testing positive for COVID-19 is a significant predicting factor for a child to be positive. Children in lower socioeconomic households can also be more susceptible, so a complete history is useful.

If the child is symptomatic, the number of days since symptoms began is important to note, especially when considering any testing. The closer the test is from the day of becoming unwell, the more reliable it is likely to be. Children may have symptoms for fewer days than adults.

Saliva tests are generally less reliable in accuracy. A PCR is the most accurate test, but RATs may be used. ANS, oropharyngeal, and nasopharyngeal swabs may be considered. Any test needs to be considered with whānau and with the current ability to accommodate your present health setting. Whānau may need some

support, and if they wish to take a swab from the child themselves, this should be considered. Manufacturer guidelines and swab size also need to be considered.

When testing, you may wish to consider differential diagnoses such as RSV, influenza or other causes for completeness.

A child-friendly approach by trained staff is essential (see Appendix C).

Draft Whānau Information Sheet and Child Story for Local Adaptation

These information pamphlets were drafted as a guide to present to families in a clinical setting to aid information sharing. They are not intended to take the place of discussion and decision-making and may not suit all whānau. The child's story may be something that can be read between caregivers and child or health professional and child. They were developed with the help of a preschool consultant and nurse educator (see Appendix C).

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Appendices

Appendix A: Characteristics of Included Studies

Author, (Year), Country	Design	Participants	Data collection	Findings	Implications for practice	JBI score
Chiwandire et al. (2023), South Africa	Retrospective quantitative study	All recorded COVID-19 cases and hospital admissions with COVID-19 in South Africa between March 1, 2020, and February 5 2022	Data was gathered from two databases in South Africa: the laboratory-based COVID-19 Notifiable Medical Conditions Surveillance System and the DATCOV COVID-19 Hospital Surveillance system storing information on all COVID-19 PCR or antigen tests (positive and negative), and all hospital admissions with COVID-19	Population estimates at publication were under 1 year = 2%, 1–4 years = 7.5%. COVID-19 testing under 1 year = 2.2%, 1–4 years = 2.1%. Confirmed cases under 1 year = 0.3%, 1–4 years = 1.2%. COVID-19 hospital admissions under 1 year = 1.2%, 1-4 years =1.3%. Deaths under 1 year = 0.3%, 1–4 years = 0.1%. COVID-19 testing overall was lower for children than adults. Hospital admission rates were highest for under 1-year-olds across the pediatric range. Infants had the highest rates for testing, admission, and in-hospital case fatality in all waves, including the fourth	Vaccination should be expanded to children aged 5–11 years with underlying illnesses	8/9
Title: Changing epidemiology of COVID-19 in children and adolescents over four successive epidemic waves in South Africa, 2020–2022 **Aim:** To describe the changing testing patterns and evolving epidemiology of diagnosed SARS CoV-2 infections, hospitalizations, and deaths in children and adolescents aged ≤18 years in South Africa over four successive waves of infection and compare these to trends in adults						
Cohen et al. (2020), France	Cross-sectional prospective multicentre study	0–15-year-olds consulting paediatricians between April 14, 2020, and May 12 2020, who were either pauci-symptomatic or asymptomatic or previously symptomatic. Children who required hospital care or treatment were excluded	27 ambulatory paediatricians collected symptomology, socioeconomic data, duration of symptoms, an NPS sample, and a fingerpick blood test for serology	Among the 605 children, 322 (53.2%) were asymptomatic and 283 (46.8%) were symptomatic. Reverse transcription-PCR and serology results were positive for 11 (1.8%) and 65 (10.7%) children, respectively, with no significant difference between asymptomatic and pauci-symptomatic children. Only 3 children were reverse transcription-PCR-positive without any antibody response detected. The reverse transcription-PCR COVID-19 positivity frequency was significantly higher for children with positive than negative serology results. Contact with a person with confirmed COVID-19 increased the odds of reverse transcription-PCR positivity (OR 7.8,	The only factor associated with reverse transcription-PCR COVID-19 or serology positivity was the presence of a household contact with COVID-19. The study highlights that the frequency of reverse transcription-PCR COVID-19 positivity was significantly higher in children with positive than negative serology results. This finding highlights the difficulties in interpreting the significance of a positive reverse transcription-PCR COVID-19 result without concomitant antibody testing after the epidemic wave	8/8

Author, (Year), Country	Design	Participants	Data collection	Findings	Implications for practice	JBI score
				95% CI 1.5–40.7) and serology positivity (OR 15.1, 95% CI 6.6–34.6)		
Title: Assessment of SARS-CoV-2 infection by reverse transcription-PCR and serology in the Paris area: A cross-sectional study **Aim:** To best approach the prevalence of SARS-CoV-2 in children at a population level, this study combined both reverse transcription-PCR testing for SARS-CoV-2 and serology in asymptomatic or pauci-symptomatic children						
Engels et al. (2022), Germany	Non-randomised controlled trial, pilot study	At the nine participating DCCs, there were 836 children (range 31–130) and 190 CCWs (range 12–28)	Parents of children aged 2–6 years and CCWs could opt for 1 of 3 approaches (i.e., groups) for continuous twice-weekly COVID-19 testing by home-based self-sampling for a period of 12 weeks. Group 1 performed self-sampling of mouth-rinsing fluid (saliva sampling [SAL]) for subsequent pooled PCR testing plus a nasal swab-based RAgT, both conducted on the same day; group 2, only SAL; and group 3, only RagT. Parents also answered questionnaires. Antibody serology testing was undertaken prior and post testing	215 (47.6%) opting for group 1 (SAL plus RAgT), 172 (38.1%) for group 2 (SAL only), and 65 (14.4%) for group 3 (RAgT only). Of these parents, 281 of 325 (86.5%) considered access to the DCC as fairly or very important for their daily life; 116 of 323 (35.9%) and 247 of 324 (76.2%) considered COVID-19 as fairly and very dangerous, respectively, to their family or society, and 186 of 324 (57.4%) felt fairly or strongly limited in their personal lives. One child tested positive by SAL. At week 12, COVID-19 antibodies were detected in 6 of 278 children (2.2%). Five of these six children (83.3%) already had antibodies for COVID-19 at week 1. Most parents considered screening useful (at week 1: 192 of 221 [86.9%]; week 12: 191 [86.4%]) and the test frequency (i.e., twice a week) appropriate (week 1: 200 [89.7%]; week 12: 203 [91.8%]). They were satisfied with the self-sampling process (week 1: 180 [81.1%]; week 12: 173 [77.9%]) and reported no negative impact on the organisation of their daily life (week 1: 210 [95.5%]; week 12: 208 [94.5%]). For saliva testing, 100 of 112 parents (89.3%) and 102 (91.1%) reported “very good cooperation” from their children in weeks 1 and 12, respectively, vs 46 of 93 (49.5%) and 43 (46.2%) for RAgTs in weeks 1 and 12, respectively. In week 1, 80 of 125 parents (64.0%) and in week 12, 92 parents (73.6%) stated that their children “did not like” the RAgT	In this study, home-based continuous testing for COVID-19 by PCR from saliva samples and RAgT from nasal atrium was generally well accepted by children and CCWs. Less invasive saliva sampling was the preferred test method with the highest long-term acceptance levels. Acceptance of testing declined during the study, in parallel with decreasing COVID-19 incidences, increasing vaccination coverage of CCWs and parents, and a decrease in the perceived threat posed by the pandemic. If the objective is to exclude COVID-19 introduction to DCCs with a probability of at least 95%, continuous testing in DCCs should be started at an age-adjusted incidence rate between 50 and 200 per 100,000	7/9
Title: Acceptance of different self-sampling methods for semiweekly SARS-CoV-2 testing in asymptomatic children and childcare workers at German daycare centres						

Author, (Year), Country	Design	Participants	Data collection	Findings	Implications for practice	JBI score
Aim: This study focused on non-invasive sampling combined with resource-saving pooled PCR testing and compared its feasibility with self-sampled RAgTs. The authors evaluated these continuous surveillance approaches for SARS-CoV-2 in asymptomatic children and CCWs in DCCs and analysed attitudes and psychosocial factors viewed as potentially influential factors						
Forster et al. (2022), Germany	Non-randomised feasibility study	Participants included children attending daycare, childcare workers, and household members in nine childcare centres	COVID-19 polymerase chain reaction testing of either mid-turbinate nasal swabs twice weekly (module 1) or once weekly (module 2) or self-sampled saliva samples twice weekly (module 3). Module 4 involved symptom-based, on-demand testing of children, childcare workers, and their household members by oropharyngeal swabs. All participants underwent COVID-19 antibody status testing before and after the sampling period. Questionnaires on attitudes and perceptions of the pandemic were administered in weeks 1, 6, and 12	In total, 4,755 tests for COVID-19 detected 2 infections (1 childcare worker and 1 adult household member). Acceptance for continuous surveillance was highest for biweekly saliva testing (150 of 221 eligible individuals [67.9%; 95% CI, 61.5%–73.7%]) compared with biweekly (51 of 117 individuals [43.6%; 95% CI, 35.0%–52.6%]) and weekly (44 of 128 individuals [34.4%; 95% CI, 26.7%–43.0%]) mid-turbinate swabbing ($p < .001$). Dropout rates were higher for mid-turbinate swabbing (biweekly, 11 of 62 participants [18%]; once weekly, 11 of 55 participants [20%]) than for saliva testing (6 of 156 participants [4%])	In this non-randomised controlled trial, surveillance for COVID-19 in 9 German daycare centres was feasible and well accepted. Mathematical modelling estimated that testing can minimise the spread of COVID-19 in daycare centres	7/9
Title: Feasibility of SARS-CoV-2 surveillance testing among children and childcare workers at German day care centres: A nonrandomized controlled trial **Aim:** To investigate the feasibility of surveillance among children and childcare workers and to model the efficacy of surveillance on viral spread prevention						
Fougère et al. (2021), Switzerland	Observational prospective multicentre comparative study	Symptomatic children aged 1 month to 18 years presented to two different outpatient clinics for COVID-19 testing between November 4 and December 12, 2020	Saliva samples were collected by or under the guidance of a healthcare professional, an NPS was taken, symptomology and demographic information were recorded along with the quality of the saliva specimen collected	397 children who had both NPS and saliva samples were included in the findings. 31 of these were under 6 years old. The detection rates significantly differed between the age groups of 0–6 and ≥6–12 years (3.2% vs 30.7%; $p = .004$). Only 4 children under 6 years of age were detected positive from NPS, with only 1 child being documented positive from saliva. Only 15 children in this age group were able to drool saliva (15/31). Lower VLs documented from saliva in younger children and those with longer duration of symptoms likely limited the diagnostic performance of saliva in children	While RT-PCR testing on saliva performed more poorly in younger children and likely after a longer duration of symptoms, saliva remains an attractive alternative to NPS in children	7/10
Title: Performance of RT-PCR on saliva specimens compared with nasopharyngeal swabs for the detection of SARS-CoV-2 in children						

Author, (Year), Country	Design	Participants	Data collection	Findings	Implications for practice	JBI score
Aim: To prospectively compare the paired saliva and NP samples collected from symptomatic children for the detection of SARS-CoV-2. The secondary objectives were to compare discordant NP and saliva RT-PCR findings as well as their viral loads						
Hurst et al. (2021), USA	Prospective cohort study	Participants were under 21 years old and identified either through presentation to the health system themselves with COVID-19 or through presentation of a close contact with laboratory-confirmed COVID-19 infection. Data was collected between April 7, 2020, and July 16 2020.	The study collected exposure, sociodemographic, and clinical data at enrolment through review of electronic medical records, a directed caregiver questionnaire conducted by telephone, and COVID-19 PCR test results. Mid-turbinate swabs were either performed by participants or their caregiver, and NPS performed by medical staff	Of 382 children, 293 (77%) were COVID-19-infected. COVID-19-infected children were more likely to be Hispanic ($p < .0001$), less likely to have asthma ($p = .005$), and more likely to have an infected sibling contact ($p = .001$) than uninfected children. Despite the age-related variability in symptoms, the study found no difference in nasopharyngeal viral load by age or between symptomatic and asymptomatic children	Hispanic ethnicity and an infected sibling close contact are associated with increased COVID-19 infection risk among children, while asthma is associated with decreased risk. Age-related differences in clinical manifestations of COVID-19 infection must be considered when evaluating children for coronavirus disease 2019 and developing screening strategies for schools and childcare settings	7/9
Title: Severe acute respiratory syndrome coronavirus 2 infections among children in the Biospecimens from Respiratory Virus-Exposed Kids (BRAVE Kids) study **Aim:** To describe risk factors, clinical manifestations, and nasopharyngeal viral loads of SARS-CoV-2 infection in people aged under 21 years						
Kumar et al. (2022), India	Retrospective diagnostic test study	Neonates presenting to an ED with either a COVID-19 positive mother or other COVID-19 positive contact or a respiratory illness	All neonates consecutively referred to the institute from August 1 to December 31, 2020, were enrolled. Initial criteria for testing were certain contact with COVID-19 cases and respiratory distress within clinical guidelines. From August 20, 2020, onwards, a universal screening policy was adopted in which all symptomatic patients (irrespective of illness) reporting to the emergency underwent COVID-19 testing	1,225 neonates were admitted, of which 875 had respiratory distress at admission. COVID-19 RT-PCR test was conducted in 969 of 1,225 (79.1%) neonates, 17 of which were positive, and 5 of these died. Most (11/17) presented in the first 2 weeks of life, and almost all (14/17) presented with respiratory distress. Neonates having fever at admission had significantly higher odds of having COVID-19 (95% CI: 3.3-47.9, $p = .004$; OR: 12.5). However, there was no difference in cough, respiratory distress, prior hospitalisation, or need for mechanical ventilation. If the selective testing policy had been followed, only 9/17 COVID-19 cases (53%) would have been diagnosed. Therefore, the universal testing policy identified an additional eight (47%) cases	Although neonates with a positive screen at admission had higher odds of COVID-19, the sensitivity was poor (43% of confirmed COVID-19 cases had a negative screen). These observations support a universal testing screening policy. The practice of universal testing of all out born neonates requiring admission was not based on neonatal data but rather an extrapolation from older age groups. This study provides some evidence for this practice, although the numbers are not large enough to make conclusive recommendations	6/10
Title: Clinical characteristics & outcome of SARS-CoV-2 infected neonates presenting to paediatric emergency **Aim:** To assess the positivity rate, characteristics, and outcome of COVID-19 among out born neonates presenting to the paediatric emergency in a tertiary care centre						

Author, (Year), Country	Design	Participants	Data collection	Findings	Implications for practice	JBI score
Lee et al. (2023), USA.	Diagnostic feasibility testing study	23 ECE sites were selected based on their eligibility to participate in either the Child and Adult Care Food Program or the National School Lunch Program to reach an intended low-income population. Flyers were handed out and volunteers took a one-off test. A total of 217 parents and 217 children were included	Children needed to collect saliva by spiting down a straw collection device. Children were questioned on the ease of sampling, how fun it was, and the likelihood of doing it again with a smiley face chart. Parents were questioned on the difficulty for the child, satisfaction, time taken and if they would recommend it. Tests were timed, and demographic data was collected	Surveys in English or Spanish administered at testing events to children and caregivers at ECE sites showed child and adult acceptability and feasibility ratings were generally high. More favourable child and parent ratings were positively associated with the child's age and whether the child was able to produce a saliva sample. Language preference was not associated with any outcomes.	This study demonstrated that saliva-based COVID-19 testing with young children, parents, and teachers at ECE sites is generally well received and may serve as an additional layer of protection to ensure children's safe return to ECE in the wake of the pandemic. Alternative strategies may be needed for younger children (0–3 years) to participate in ECE site-based COVID-19 screening	8/8
Title: Acceptability and feasibility of saliva-delivered PCR coronavirus 2019 tests for young children **Aim:** To determine the acceptability and feasibility of using a quantitative polymerase chain reaction COVID-19 saliva test for young children (ages 3–5) and their caregivers (parents and teachers) as part of a safe return to school study						
Moraleda et al. (2022), Spain	Cross-sectional multicentre diagnostic study	Children from 0–18 years with symptoms compatible with COVID-19 of ≤ 5 days of duration were included from 10 hospitals in Spain between February and March 2021. Included were 1,174 children. 516 participants were 3 years of age or younger	Two NPS samples and one OSS sample for RT-PCR were collected by trained nurses. Patients with discordant diagnostic test results from any of the three different tests were invited to a second visit and a blood sample was drawn for COVID-19 IgG detection	In total, 73/1174 (6.2%) patients tested positive by at least one of the diagnostic techniques. Out of those 73 patients, 68 tested positive by NPS RT-PCR (5.8% of the total; 93.2%), 53 by OSS RT-PCR (4.5% of the total; 72.6%) and 43 were positive by NPS Ag-RDT (3.7% of the total; 58.9%). Moreover, analysis by age showed that the accuracy for NPS and OSS is similar (≤3 years vs >3 years), unlike the Ag-RDT, which performed poorly in children under 3 years	RT-PCR on the OSS sample is an accurate option for COVID-19 testing in children. A less intrusive technique for younger patients, who usually are tested frequently, might increase the number of patients tested. Saliva swabs may be more acceptable for younger patients than nasopharyngeal swabs, possibly increasing the testing capacity in this age group	9/10
Title: Oral saliva swab reverse transcription PCR for Covid-19 in the paediatric population. **Aim:** To evaluate the performance of oral saliva swab reverse transcription PCR compared with RT-PCR and antigen rapid diagnostic test on nasopharyngeal swabs for COVID-19 in children						
Olivar-López, et al. (2020), Mexico	Analytical cross-sectional study	Patients under 18 years of age who came for a consultation with a clinical picture compatible with COVID-19 (fever, respiratory symptoms, or general malaise) and who underwent RT-PCR	Clinical data, COVID severity, age, pre-existing co-morbidities, and outcomes were classified and recorded. During the study time frame, 540 tests were taken (30 were discarded due to poor technique or insufficient	Total in study-infants, 148 (29%); preschoolers, 134 (26.7%). When comparing subjects with and without COVID-19 infection, the only variable that showed statistical differences was the history of contact with a positive case (27.6% vs 57.9%). Infants and adolescents represented 64% of confirmed cases. When comparing the presentation of symptoms between age	Infants and adolescents with sudden onset of symptoms (chest pain for children who could report it) and a history of contact with a confirmed COVID-19 patient may be the primary factors to be screened for with testing	6/8

Author, (Year), Country	Design	Participants	Data collection	Findings	Implications for practice	JBI score
		testing were included in the study	sample), and 510 patients were included	groups in patients with COVID-19 infection, those that presented differences were dyspnoea, irritability, shivers, myalgias, arthralgias, general malaise, and abdominal pain		
Title: Clinical risk profile associated with SARS-CoV-2 infection and complications in the emergency area of a pediatric COVID-19 centre **Aim:** The objective of this study was to describe the profile of patients under 18 years of age treated at a pediatric COVID centre and its association with test confirmation, endotracheal intubation, and death						
Oliver et al. (2021), Australia	Prospective multicentre diagnostic validation study	1,050 people who provided paired saliva and oropharyngeal nasal swabs for COVID-19 testing were included. The authors prioritised recruiting people with confirmed COVID-19 infections and close contacts of people with confirmed COVID-19 infections	Participants at the clinics and hospitals were asked to collect saliva and oropharyngeal specimens and then complete some questions on their collection preference. Testing was in line with COVID-19 testing criteria at the time	In under 5 years, 33% of infections were picked up by saliva alone, 53% by swab alone, and 13% by saliva and swab. 91% of children under 5 years preferred saliva collection	In children over 10 years of age and adults, saliva testing alone may be suitable for COVID-19 detection, while for children under 10, saliva testing may be suitable as an adjunct to oropharyngeal nasal swab testing for increasing case detection	9/10
Title: Adding saliva testing to oropharyngeal and deep nasal swab testing increases PCR detection of SARS-CoV-2 in primary care and children **Aim:** To compare the concordance and acceptability of saliva testing with standard-of-care oropharyngeal and bilateral deep nasal swab testing for severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) in children and in general practice						
Weng et al. (2021), USA	Retrospective cohort study	All patients who received COVID-19 NPS PCR on or before June 22, 2020, and were 17 years old or under at the time of the test. The study included patients whose exposure and symptoms were evaluated either before or after PCR testing	NPS sample, as well as demographic data and a standardised template to verbally query symptoms from patients or their caregivers. Myalgia, headache, sore throat, abdominal pain, nausea, and anosmia or ageusia were not assessed in children aged 0–4 years old due to their lower ability to report these symptoms	Of 555 participants, 217 (39.1%) were COVID-19-infected. Fever was more common among 0–4-year-olds, followed by cough, rhinorrhoea, diarrhoea, dyspnoea, fatigue, and nausea. The only statistically significant finding was that exposure to COVID-19 and a cough increased the likelihood of testing positive for COVID-19	In all ages, exposure history most accurately predicted infection. Anosmia or ageusia is highly specific in children over 5 years old and dyspnoea in children 5–11 years old and should raise providers' index of suspicion for COVID-19; however, the sensitivity of this symptom is low. The overall findings underscore the limited diagnostic value of symptoms and the critical need for widely available, efficient testing	9/10
Title: Diagnostic value of symptoms for pediatric SARS-CoV-2 infection in a primary care setting **Aim:** The study analysed data from a primary care setting to evaluate the diagnostic value of symptoms used by daycares and schools to screen children and adolescents for SARS-CoV-2 infection						
Westbrook et al. (2022), USA	Quasi-experimental study	Patients aged 0–18 years presented to one of six clinics for COVID-	Individual symptoms were gathered, face to face, at the time of testing. Contact with	Unlike school-aged children, infant, and early childhood–aged children with 1 symptom or ≥2 symptoms were not more likely to test	With high Delta variant prevalence, children with isolated symptoms were as likely as those with multiple	7/9

Author, (Year), Country	Design	Participants	Data collection	Findings	Implications for practice	JBI score
		19 testing between July 4 and October 15 2021	COVID-19 and vaccination status were also requested. Participants were classified into three groups: asymptomatic, 1 symptom only, or ≥2 symptoms. COVID-19 test results and clinical characteristics of the three groups were compared	positive for COVID-19 than children with no symptoms, though as in the older children, the likelihood of having COVID-19 did not differ between those with 1 or ≥2 symptoms. These patterns remained similar when those who presented with fever were excluded and after adjustment for exposure status and vaccination status	symptoms to test positive for COVID-19. Isolated fever, cough, sore throat, or headache, but not congestion/rhinorrhoea, offered the highest predictive value. These results suggest that school and daycare policies should consider isolated symptoms as potential triggers for exclusion and testing	
Title: Predictive value of isolated symptoms for diagnosis of severe acute respiratory syndrome coronavirus 2 infection in children tested during peak circulation of the Delta variant **Aim:** In this study, rates of COVID-19 in children presenting for testing in a high prevalence area during peak circulation of the SARS-CoV-2 Delta variant who reported no symptoms, 1 isolated symptom, or ≥2 symptoms were compared. Additionally, the predictive value of each isolated symptom and the impact of age, close contacts, and vaccination status on the likelihood of having COVID-19 was evaluated						
Zhou et al. (2022), USA	Cross-sectional, retrospective study	Symptomatic 0–18-year-olds were referred to three outpatient clinics for COVID-19 testing between April and November 2020. Children tested were referred by an advice nurse or other outpatient paediatric provider for evaluation and COVID-19 testing	PCR COVID-19 testing, and symptom screening conducted by a healthcare provider either by phone or in person. Set symptoms from the CDC as well as school exclusions ere included. Some variations in symptom screening between the three sites.	2,167 children were included in this study, of which 960 (44.3%) were aged 0–4 years. 76 (31.5%) of these children tested positive. For those children with reported exposure, the percentage positive was higher across all symptoms compared to those without exposure. In 0–4 years olds, fever/cough/ loss of taste was the predominant symptom, followed by fever/chills, nasal congestion/rhinorrhoea, cough, nausea/vomiting/diarrhoea	The presence of most symptoms did not meaningfully increase the likelihood of testing COVID-19 positive, especially in children with no known COVID-19 exposure. This suggests that a more limited symptom list could be used as the pandemic evolves to create more parsimonious symptom criteria for exclusion and testing. Excluding students or staff with non-specific symptoms was unlikely to identify children effectively or efficiently with COVID-19 and likely contributed to unnecessary learning loss. The use of LRs and numbers needed to screen demonstrated that excluding and testing 5–18-year-olds with loss of taste or smell and those of all ages with exposure to COVID-19, would have been reasonable approaches to identify COVID-19 cases during the study period	9/9
Title: Utility of illness symptoms for predicting COVID-19 infections in children **Aim:** To assess the potential impact of exclusion and testing of symptomatic children on detection of COVID-19 and on school or childcare days missed						

Note. PCR = Polymerase chain reaction; RT-PCR = Reverse transcription polymerase chain reaction; ED = Emergency department; CI = Confidence interval; CDC = Center for Disease Control; LR = Likelihood ratio; OR = Odds ratio; RAgT/AgRDT = Rapid antigen test; OSS = Oral saliva swab; VL = Viral load; NPS = Nasopharyngeal swab; DCC = Daycare centre; CCW = Childcare worker; ECE = Early childcare centre.

Appendix B: Parent's COVID-19 Handout

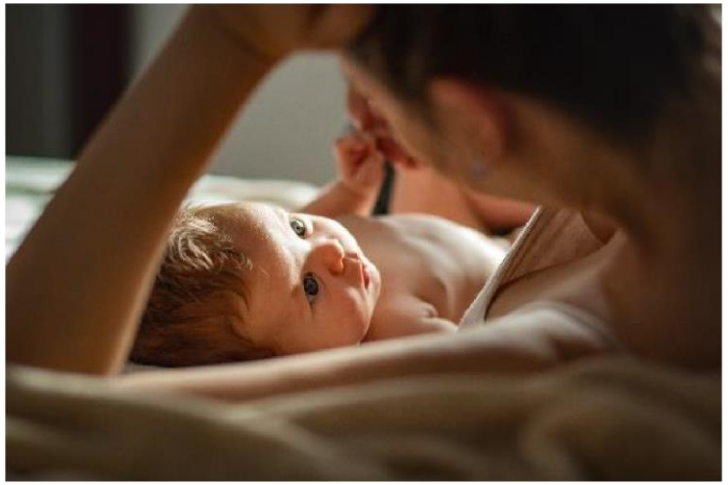
To stop the spread of COVID-19 we may need to test your child. Several tests are available. The most common tests are done by taking a swab of the inside of the nose, the back of the nose, or the back of the throat. Sometimes a combination of testing in more than one place is recommended (like testing the back of the throat and the nose on the same swab). This is safe to do.

You may have heard about saliva tests, but these are not often offered as they have less accuracy than the nose and throat swabs.

As a caregiver you need to be comfortable with any tests on your child. Please ask any questions you have. You could choose to do the swab yourself with some guidance from the health professional. You could choose to hold/ hug your child while a health professional does the test, or you may prefer not to.

We want to work with you today to help improve the health of your child and whanau, so if you have questions or suggestions, please let us know.

COVID-19 and your baby or preschooler



If your Child Has....

Fever (high temperature)

Your child may feel warmer than usual, or if you measure their temperature, it may be higher than 38 degrees.

Cough

Your child may have a cough or be upset with a sore throat.

Runny nose

You may notice discharge from your child's nose, or they may be breathing through their mouth due to a blocked nose.

Vomiting (throwing up feeds) or diarrhoea (runny poos)

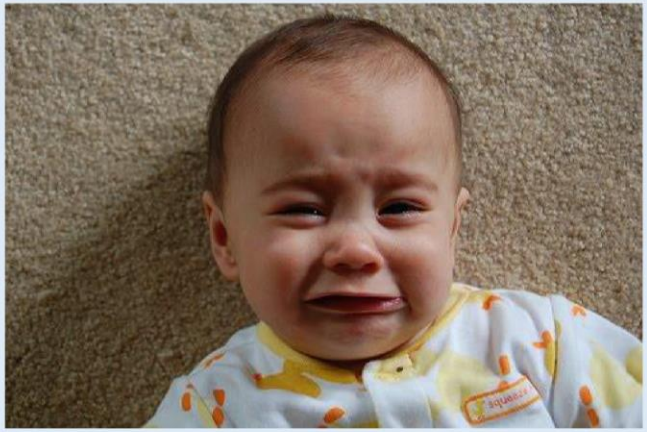
Some children with COVID-19 present with an upset tummy-you may have noticed them being off their feeds or throwing up, or changes in their bowel motions (poos).

…they may have COVID-19 or another virus.

There are many reasons for the symptoms described here. Sometimes it is useful to do testing to ensure your child gets the best treatment to help them to get better.

The health professionals will ask you questions to help guide the diagnosis and any necessary treatments. Please give all the information you think is helpful to the health professionals so you can work together to help your child.

Appendix C: Children's COVID-19 Handout



Are YOU feeling Sick Today?

Sometimes you feel sick/ turoro....
You might have a cough/ mare....
Or vomit/ Ka ruaki ahau....
Or an ouchy tummy/ puku.

Your whanau might take you to see a doctor or nurse/ takuta/ nahi.

The doctor and nurse/ takuta/ nahi will ask your whanau some questions. They might talk/ korero for a little bit.

Then the doctor or nurse/ takuta/ nahi might want to talk to you. They might want to touch your fingers/ matimati or see how big you can open your mouth/ waha. They might look in your ears/ taringa even! It won't hurt. They want to check that you are okay/ ka pai.

Then they might want to do a little tickle test in your nose/ ihu. They take a very little stick and tickle/ ngaoko inside of your nose- it might feel like when you pick your nose! The tickle nose test doesn't take long, and you can help do it too if you want.

Then the doctor and nurse will then talk to you and your whanau about how to make you feel better/ tuhauora