



Non-Pharmaceutical Measures to Prevent Influenza Transmission: The Evidence for Individual Protective Measures

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Introduction

A wealth of knowledge has become available concerning influenza prevention and control in the wake of the 2009 H1N1 pandemic. The purpose of this review is to summarize the recent literature on several non-pharmaceutical interventions: masks; quarantine, isolation, and social distancing; and hand hygiene, respiratory hygiene, and cleaning of fomites.

Masks

A recently updated Cochrane review concluded that mask use can interrupt the transmission of influenza (1). While the review found evidence for the efficacy of this approach, the study did not examine the real-world effectiveness of mask-wearing, given the inconvenience and costs of the strategy.

Mask use to prevent influenza transmission can be divided into four categories of users: health care personnel, symptomatic individuals, well individuals exposed to household contacts with influenza, and well individuals in

Key Points

- Mask use by cases and/or household contacts may be efficacious in reducing the transmission of influenza, but that effectiveness is likely reduced by poor compliance. Mask use in the community setting is of dubious benefit, as is the use of N95 respirators rather than surgical masks outside of health care settings.
- Isolation and quarantine are effective and acceptable interventions to reduce the spread of influenza, particularly pandemic influenza. Social distancing measures (excluding school closures and prohibitions on mass gatherings, which are covered in another paper in this series (Roth, 2011)), however, are of unproven value and associated with low uptake. Special attention should be paid to providing tools and supports to those in quarantine or isolation, particularly to vulnerable groups.
- Moderate evidence exists to support recommendations for hand and respiratory hygiene, especially in children. Further research is needed to show benefits from cleaning and disinfection of surfaces in household and public spaces.

public spaces. Recommendations for mask use among health care personnel are summarized elsewhere (e.g. see Carlson et al, 2010 (2)). Here, we review recent literature on mask use for ill and healthy individuals in the community and summarize recent recommendations regarding the utility of N95 respirators *versus* surgical masks.

Mask Use by Symptomatic Individuals and Their Household Contacts

A systematic review (3) found some evidence to support the use of masks by symptomatic individuals. Most of the studies reviewed had both index cases and household contacts instructed to



wear masks, thereby creating difficulty identifying where an interruption in influenza transmission occurred. They do, however, cite an experimental study of infectious volunteers with influenza, supporting the conclusion that surgical masks provide outward protection (i.e. mask-wearing by a case reduces the likelihood that the case will infect others) (4). The review finds less evidence to support the use of masks in household contacts of cases and suggests that such interventions would result in difficulties with compliance (3).

Several recent randomized controlled trials (RCTs) have attempted to determine the effectiveness of masks and hand hygiene in preventing primary and/or secondary transmission of influenza compared to hand hygiene alone and to a usual practice control group. One study found no decrease in overall rates of upper respiratory infections in those houses using masks, but did find mask wearing associated with reduced secondary transmission (despite poor adherence) (5). Another trial also found no significant difference in influenza infection between the three arms of their study (where households with a member presenting to clinic with influenza-like illness [ILI] were assigned to the control group, the soap/hand sanitizer supplies and education group, or the third group which received soap/hand sanitizer supplies and education plus surgical mask provision and education), but did see a reduction in influenza transmission in the mask plus hand hygiene group when the intervention was implemented within 36 hours of symptom onset (6). In these studies both index cases and household contacts were instructed to wear masks, making it difficult to isolate the effectiveness of mask-wearing by index cases *versus* contacts. A final RCT recruited households of children presenting to clinics with ILI and assigned them to the control intervention, surgical masks, or N95-equivalent masks, with

recommendations for household contacts only to wear them. Although there was no significant difference in the transmission risk of ILI between the three study arms in an intention-to-treat analysis, adherent use of either surgical masks or N95-equivalent masks was the only variable that was significantly associated with a reduced risk of ILI infection among household contacts of cases (7).

Among possible interventions to reduce the spread of influenza, mask-wearing by students was rated the lowest median acceptability in a survey of teachers, and mask-wearing while caring for ill children

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was the least acceptable of interventions proposed to parents (8). Similarly, surveyed university students were more resistant to wearing a mask in public if experiencing influenza-like symptoms than to any other proposed strategy (including isolation and vaccination) (9).

Mask Use in Public Spaces

Mask use in the general public is predicated on the assumption that a significant proportion of transmission events will occur in public spaces. Evidence for this assumption is limited. Among recent literature on the subject, a RCT found mask-wearing plus hand hygiene in university dormitories decreased the

weekly ILI attack rate during some weeks of the trial, but found no difference in the cumulative attack rate (10).

As with mask use by cases and household contacts, poor compliance could decrease the effectiveness of mask use in public settings. Observed rates of mask wearing on Mexico City public transportation early in the 2009 H1N1 pandemic were above 60%, but declined to below 40% within a week (11), although only a slight decrease was reported in Hong Kong (12). Two Australian surveys, conducted before and after the pandemic, found a significant decrease in subjects' willingness to wear a mask in public (13, 14). A pandemic model, however, suggests that even if masks were only 20% effective and only 10% of the population wore them during a pandemic, cases of influenza would be reduced by 20%; masks that were 6% effective worn by 50% of the population would reduce cumulative cases by only 6% (15).

Mask Type

Debate over the utility of N95 respirators *versus* surgical masks for the prevention of influenza transmission is based to a large extent on uncertainty about the relative importance of various modes of transmission. Supporters of the key role of aerosol transmission, such as in a recent expert-led review (16) and mathematical model (17), encourage the use of N95 respirators because they provide better filtration of small particles under ideal conditions. Critics can point to a recent model citing contact between virus-laden hands and facial membranes as the key transmission route (18), which is supported by reviews finding no difference in attack rates for influenza between masks and respirators (1, 19). Given that the RCT comparing the two types of masks in households was underpowered to detect a difference (7), resolution of this debate is still forthcoming.

Overall, these results suggest mask use by cases and/or household contacts may be efficacious in reducing transmission of influenza, but that effectiveness is likely reduced by poor compliance. Mask use in the community setting is of dubious benefit, as is the use of N95 respirators rather than surgical masks outside of health care settings.

Quarantine, Isolation, and Social Distancing

Measures to reduce interactions between ill and healthy individuals are some of the oldest interventions in the battle against infectious diseases. For the purposes of this paper, these measures will be defined as follows:

- Isolation is the separation of ill individuals from others for the period of infectiousness.
- Quarantine is the separation of exposed individuals until it is clear they are not infectious (generally for the incubation period of the illness).
- Social distancing includes measures to reduce contacts with individuals of unknown illness status, such as avoiding public transit and telecommuting. School closures and prohibitions on mass gatherings are included in this definition, but are covered in depth in another paper in this series (Roth, 2011).

As these measures are often explored together in the literature, they will be presented together here by study design.

Models

Most models explore combinations of strategies to reduce the impact of pandemic influenza, including quarantine, isolation, school closures, workplace closures, antiviral treatment and prophylaxis, and vaccination. Not surprisingly, combined preventive methods are more effective than solitary

strategies, according to a systematic review of pandemic models (20). School closures, social distancing of adults and children, and targeted antivirals were associated with lowering the attack rate from 35% to 10% when the reproduction number (R_0) was greater than 2.1 in one model; the preferred strategy for an R_0 below 1.6 was social distancing and antivirals alone (21). Another study found that, for an R_0 of 1.5, a combination of school closures, in-household isolation, workplace non-attendance, and reduction of community contacts implemented 6 weeks after identification of the first case could lower the cumulative attack

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rate from 33% to 10% (22). In the same model, case isolation alone could achieve a comparable outcome if implemented within 3 weeks of introducing the first case (22); an alternative model found case isolation associated with a one-third reduction in the attack rate (23).

Combined interventions are most effective at lower values of R_0 (22, 24). To have an impact on overall attack rates, these interventions must be implemented early (22, 25) and kept in place until a vaccine is available (22, 24). Targeting interventions to the age groups with the highest incidence of infection provides optimum effectiveness (26).

Economic models balance the costs of pandemic-associated morbidity and mortality against the cost of implementing

given interventions. Two models from the UK found that the expected impact of a pandemic was small (0.5%-2% of GDP) and that the bulk of the economic impact would come from quarantine and school closures (27, 28).

Focus Groups, Interviews, and Surveys

Even if efficacious under ideal circumstances, quarantine, isolation, and social distancing will be ineffective at controlling pandemic influenza if adherence to these measures is low. A variety of studies have examined individuals' attitudes and intentions regarding such strategies through focus groups, interviews and surveys. A smaller number of studies have examined the reported behaviours of those who have experienced pandemic influenza in their region.

The primary barriers to undertaking quarantine and isolation were economic disincentives, as many subjects did not have sick leave and could not afford periods without pay (13, 29-32). Another important barrier for those considering quarantine or isolation was the lack of access to essential goods and services (29, 32). Participants in one series of focus groups suggested that isolation of an ill family member within the house would be hindered by the need to care for that person and by space constraints due to the size of the home (33).

The majority of subjects questioned in surveys and focus groups indicated a willingness to take part in quarantine and/or isolation if necessary, often out of a desire to protect others or to fulfill their civic duties (8, 13, 34-36). Researchers conducting focus groups in Canada and the UK reported that their participants looked more favourably on these interventions, perhaps because of greater trust in the government and expectation that provisions would be made for their basic needs (37,38), although Canadian

survey respondents also reported a need for safeguards to prevent the inappropriate application of quarantine (36). Groups that were more likely to intend to comply with these recommendations were women, the elderly, low-income earners and the unemployed, as well as people who attend religious services (13, 32, 34, 35). However, one Australian survey found that 27.1% of health and community service workers would not follow physician directions to stay at home with seasonal influenza (35). The same study found that, in general, people were more willing to self-isolate with pandemic influenza than with seasonal influenza or a common cold (35).

Several surveys were conducted during the 2009 H1N1 pandemic about the quarantine and isolation procedures followed by the public. Cruise ship passengers universally complied with requests to self-isolate and mostly complied with requests to self-quarantine (39). Using information self-reported by patients who had been diagnosed with pH1N1, a study in the UK found that patients made fewer daily contacts when they were ill than when they were well, particularly among those who missed work or were severely ill (40). A follow-up to an earlier Australian study, in which the authors re-surveyed their original subjects, showed that they were still willing to comply with quarantine requests but were less likely to avoid public spaces and transportation (14). In Hong Kong, social distancing efforts declined as the pandemic progressed. The authors also found that those who complied with social distancing were more likely to have other illnesses and to perceive having a higher risk of infection (12). A survey of families with a child who contracted influenza during an outbreak at a New York high school found that the highest secondary infection rate occurred among parents providing care to the index case, those providing care who slept in the same room as the index case, and siblings

watching television with the index case. Members of households who discussed influenza prevention had a 40% reduction in the risk to individual contacts (41).

Special Populations

The implications of quarantine, isolation, and social distancing vary for different subsets of the population, and several authors have attempted to explore the conditions necessary for such measures to be successful in these groups. At an Australian university, surveyed students were more likely than staff to avoid social events and public transportation but were also more likely to attend school

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if unwell, particularly if they had an exam or assignment due. Enthusiasm for online course delivery was higher among students than teachers (9).

Migrant workers in the U.S. were posited, in a non-systematic review and series of consultations with experts, to have potential difficulty isolating or quarantining themselves due to lack of sick days, fear of unemployment for missing work days, financial inability to stockpile supplies, and crowded living conditions in dormitories or hotel rooms where isolation is impossible (42). Social housing residents and low-income populations face similar issues, particularly regarding the consequences of missing work and difficulty stockpiling supplies, according to another non-

systematic review (43).

In focus groups with Australian Aboriginals, barriers to social distancing included the need to attend cultural and religious events, and the lack of clear communication about influenza that was culturally appropriate. Subjects suggested engaging local leaders as contacts to help tailor strategies and messages, and to engage with the whole community in designing pandemic plans (44).

Prospective Studies

The recent pandemic provided an opportunity to observe the effects of proximity on the transmission of pandemic influenza. Using cohorts of households with an index case, authors found conflicting results regarding how household size influences the secondary transmission rate. An Edmonton-based study of households with early laboratory-confirmed cases found larger households had increased secondary attack rates (45). A study of the households of students infected with influenza from a New York high school found that household size was not associated with secondary attack rate (46), and in two other American studies following early pandemic cases, larger household size was associated with a decrease in the secondary attack rate (47, 48).

A Korean study found that classmates, and especially roommates, of sick students at a school residence were more likely to become ill than non-classmates and roommates at the same school (49). A report from two American navy vessels supported this finding, noting that isolating an ill crew member off-ship likely prevented one vessel from a widespread outbreak experienced on her sister ship (50).

In summary, isolation and quarantine are effective and acceptable interventions to reduce the spread of influenza, particularly pandemic influenza. Social distancing

measures (excluding school closures and prohibitions on mass gatherings, which are covered in another paper in this series (Roth, 2011)), however, are of unproven value and associated with low uptake. Special attention should be paid to providing tools and supports to those in quarantine or isolation, particularly to vulnerable groups.

Hand Hygiene, Respiratory Hygiene, and Fomite Disinfection

Hand hygiene, respiratory hygiene (i.e. covering the mouth and nose with a tissue or sleeve when coughing or sneezing), and disinfection of fomites are all interventions with the potential to interrupt the transmission of influenza in households and in public spaces such as workplaces and schools. Surprisingly, despite the extensive recommendation to adopt these preventive measures, significant attention has only recently been given to studying their effectiveness outside the health care settings.

Reviews and Expert Opinion

The recent Cochrane review of physical interventions to reduce the transmission of respiratory illness found that there is evidence to recommend handwashing, particularly in young children (who are the least able to wash hands on their own and have greater social contact and infections of longer duration) (1). A review of national guidelines for non-pharmaceutical interventions for pandemic influenza noted that hand hygiene and cough etiquette were universally recommended by the 10 countries examined, and 7 of 10 also recommended that individuals avoid touching their eyes and mouths (51). This recommendation is supported by a recent Canadian non-systematic review which concluded that hand washing with an alcohol-based sanitizer or soap and water can provide adequate protection against



influenza. However, the effectiveness of other antibacterial products outside the hospital setting remains unproven (52). A literature review notes that such interventions may be difficult for those living in poverty, as they lack the financial resources to purchase supplies and may live in inadequate housing without access to warm water for handwashing or cleaning household surfaces (43).

Randomized Controlled Trials

A number of RCTs exploring the effectiveness of hand hygiene at home or school have been published in recent years. Several of these studies found no difference in primary and/or secondary transmission between those households randomized to hand hygiene (where soap and/or hand sanitizer was provided with instructions) compared to controls given educational materials about healthy lifestyles (6) or prevention and treatment of influenza (5).

An RCT in Egypt found decreases in absenteeism and ILI in schools where teachers instructed children to wash

their hands twice daily and provided information on hand hygiene. The number of laboratory-confirmed influenza cases in the intervention schools decreased by 47% (53). A similar study in Pittsburgh found that good adherence by children to hand and respiratory hygiene continued even 4 months after the intervention period (54) and that the number of laboratory-confirmed influenza A cases decreased by 52% (55). A before-and-after comparison in a Thai preschool found a decrease in ILI after implementing hand and respiratory hygiene education, mandatory vaccination, and enforced absenteeism for ill students (56). Compared to students in the control (no intervention) group of a trial conducted in a university dormitory setting, study participants who used face masks and practiced hand hygiene and those who used face masks alone showed a statistically non-significant reduction (~10%) in cumulative ILI incidence over a 6-week study period. However, when considering the latter half of the study period only (weeks 4-6), reductions in ILI incidence in the mask and hand hygiene group did achieve statistical significance,

Table 1

Summary of current findings of studies on public health measures for the prevention of seasonal and pandemic influenza, and suggestions for future research priorities

Public Health Measure	Study Findings	Suggested Research Priorities
Masks	<ul style="list-style-type: none"> • Mask use by cases and/or household contacts may be efficacious in reducing transmission. • Effectiveness of masks is likely reduced by poor compliance. • Mask use in the community setting is of dubious benefit. • N95 respirators have not been proven superior to surgical masks outside of health care settings. 	<ul style="list-style-type: none"> • RCTs that examine the effectiveness of mask use by index cases and their household contacts separately. • RCTs comparing the effectiveness of N95 vs. surgical masks with sufficient power to detect a difference.
Quarantine, isolation, and social distancing	<ul style="list-style-type: none"> • Isolation and quarantine are both effective and acceptable, particularly with regard to pandemic influenza. • Voluntary social distancing measures (e.g. avoiding public transit, telecommuting) are of unproven value and are associated with low uptake. • Special attention should be paid to providing tools and supports to those in quarantine or isolation, particularly to vulnerable groups. 	<ul style="list-style-type: none"> • Cohort studies of social contacts of ILI cases and ILI exposed individuals during incubation/infectious periods. • Prospective studies of household and social network factors that influence secondary transmission.
Hand hygiene, respiratory hygiene, and fomite disinfection	<ul style="list-style-type: none"> • Moderate evidence supports recommendations for hand and respiratory hygiene, especially in children. • There is insufficient evidence to support recommendations for cleaning and disinfection of surfaces in household and public spaces. 	<ul style="list-style-type: none"> • Evaluation of the effectiveness of communication strategies for hand and respiratory hygiene. • Effectiveness studies (laboratory and/or others) of fomite disinfection.

in contrast to the mask-only group (10).

Observational and Laboratory Studies

Investigators in New Zealand found the majority of respiratory events (coughs and sneezes) that took place in public settings (i.e. railway transport system, hospital and shopping mall) were covered by subjects' hands, followed by uncovered events. Very few respiratory events were

covered by sleeves or tissues, suggesting that respiratory hygiene messages had not reached their intended audience (57). The use of hand sanitizer also dropped in the wake of the pandemic in New Zealand (58).

Regarding cleaning products, investigators found that commercially available antimicrobial wipes outperformed the non-antimicrobial variety at reducing virus viability, but that neither was superior

to solutions of 1% bleach, 10% malt vinegar, or 0.01% dish soap (59).

Surveys and Focus Groups

Public opinion about the effectiveness and feasibility of hand hygiene and other personal protective measures in preventing pandemic influenza was mixed. For example, an Australian telephone survey showed hand hygiene was seen as an ineffective means of preventing pandemic

influenza (32). UK focus groups identified three major barriers to hand hygiene: difficulty remembering, belief that others should take more responsibility and embarrassment at being seen as engaging in “extreme measures”(33). Conversely, other studies revealed the endorsement of hand hygiene by certain sectors of the general population. Use of hygiene products (e.g. face masks and hand hygiene products) was the step that university students had most commonly taken to protect themselves from pandemic influenza (9). Parents and teachers were confident in their abilities to encourage children in hand and respiratory hygiene (8). Lastly, the majority of survey respondents in Hong Kong reported practicing hand hygiene, with numbers declining only slightly as the pandemic progressed (12).

There is evidence to support recommendations for hand and respiratory hygiene, especially in children, but further research is needed to show benefits from cleaning and disinfection of surfaces in household and public spaces.

Future Directions

Non-pharmaceutical methods have been, and will continue to be, important elements of any strategy to limit pandemic influenza. While the 2009 H1N1 pandemic provided an important opportunity to investigate the effectiveness of these approaches, much research remains to be done (Table 1).

There is a particular need for RCTs to investigate the effectiveness of mask use by cases separately from mask use by their household contacts, as well as for trials comparing the effectiveness of N95 and surgical masks outside of health care settings. To better understand adherence to quarantine, isolation, and social distancing measures (and to provide more accurate parameters for transmission models), it would be helpful to have studies that collect information on cases

or exposed individuals’ social contacts in the periods before, during, and after, their infectious or incubation periods. Prospective studies examining the social and household factors that contribute to secondary transmission would assist in identifying households at highest risk and tailoring quarantine, isolation, and social distancing strategies to the needs of different types of households. Finally, there is a need to evaluate the communication strategies used to promote respiratory and hand hygiene and to study the effectiveness of fomite disinfection in interrupting influenza transmission.

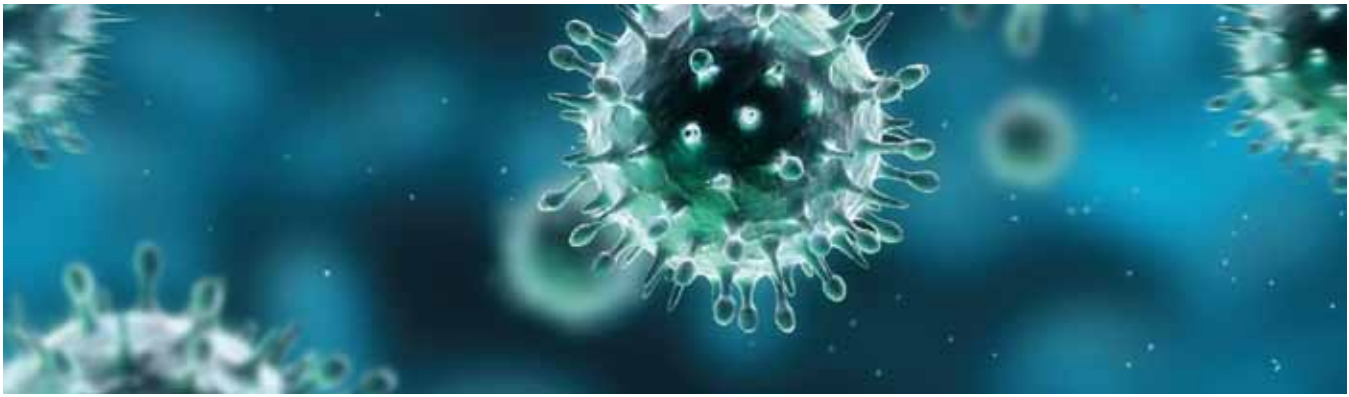
Investing in such research is key to developing evidence-based guidelines for the prevention and control of influenza. Non-pharmaceutical measures have formed the cornerstone of the public health response to influenza for centuries, and as we continue to learn how best to employ these measures, we are increasingly better-equipped to protect the health of the public during regular influenza seasons and pandemics alike.

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