Practice of Epidemiology

Social Mixing Patterns Within a South African Township Community: Implications for Respiratory Disease Transmission and Control


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A prospective survey of social mixing patterns relevant to respiratory disease transmission by large droplets (e.g., influenza) or small droplet nuclei (e.g., tuberculosis) was performed in a South African township in 2010. A total of 571 randomly selected participants recorded the numbers, times, and locations of close contacts (physical/nonphysical) and indoor casual contacts met daily. The median number of physical contacts was 12 (interquartile range (IQR), 7–18), the median number of close contacts was 20 (IQR, 13–29), and the total number of indoor contacts was 30 (IQR, 12–54). Physical and close contacts were most frequent and age-associative in youths aged 5–19 years. Numbers of close contacts were 40% higher than in corresponding populations in industrialized countries (P < 0.001). This may put township communities at higher risk for epidemics of acute respiratory illnesses. Simulations of an acute influenza epidemic predominantly involved adolescents and young adults, indicating that control strategies should be directed toward these age groups. Of all contacts, 86.2% occurred indoors with potential exposure to respiratory droplet nuclei, of which 27.2%, 20.1%, 20.0%, and 8.0% were in transport, own household, creche/school, and work locations, respectively. Indoor contact time was long in households and short during transport. High numbers of indoor contacts and intergenerational mixing in households and transport may contribute to exceptionally high rates of tuberculosis transmission reported in the community.

disease transmission, infectious; models, theoretical; particulate matter; respiratory tract infections; social behavior; tuberculosis, pulmonary

Abbreviation: HIV, human immunodeficiency virus.

Respiratory diseases are major causes of morbidity and mortality in Africa (1–3). Africa’s population reached 1 billion in 2009, with 40% living in cities (4). While urbanization can be associated with improved human development, social mixing increases the potential for person-to-person disease spread. Urban economies are lagging behind population growth, resulting in large numbers of people living in slum conditions (4). Person-to-person contact within these poor communities, with high rates of human immunodeficiency virus (HIV) disease and low access to basic amenities, further puts these populations at increased risk of epidemic and endemic infectious diseases, including respiratory diseases (1–3, 5, 6). In South Africa, which has high rates of urban migration, residents of townships have one of the highest tuberculosis notification rates in the world, with over 1% of the population developing active tuberculosis annually (7–9).

Transmission of communicable diseases results from exposure of susceptible hosts to infectious organisms under pro-pitious conditions. Infectious respiratory pathogens spread by means of either large respiratory droplets or small droplet nuclei. Viral infections (e.g., influenza) are thought to be spread predominantly by large respiratory droplets which become trapped in the nasal passages of a new host (10–13). A single sneeze can produce 2 million infectious particles, which not only remain airborne but can also contaminate and survive in the environment (11, 14, 15). Hands may become...
contaminated, with subsequent transfer of virus to the oral or nasal mucosa of a new host. Although the quantitative contribution of direct physical contact to influenza spread is unknown, hand-washing is widely promoted as a control strategy (16–19).

In contrast, tuberculosis is predominantly transmitted by small infectious droplet nuclei which remain airborne longer than larger particles and are able to be inhaled and reach the lung alveoli (20). One cough and 5 minutes of loud talking produce similar numbers of infectious droplet nuclei, which can remain airborne for up to 30 minutes (21). Transmission therefore results from time-dependent exposure to infected air (22, 23). Ventilation dramatically dilutes the concentration of infectious droplet nuclei, so that transmission occurs predominantly within poorly ventilated indoor settings (22–26).

We explored the role of different person-to-person social interactions in the potential for respiratory disease spread within a crowded South African township. Social mixing patterns were quantified by means of a randomly selected population sample using a diary record of all social contacts made during a 24-hour period. The numbers of physical and nonphysical close contacts recorded by participants were used to model the potential for spread of influenza-like illnesses. We analyzed indoor contacts by location to identify settings conducive to tuberculosis transmission by small infectious droplet nuclei.

MATERIALS AND METHODS

Population size and age distribution

The study population comprised residents of a poor township 40 km south of Cape Town, South Africa, that is highly affected by HIV and endemic tuberculosis (8, 9, 24, 27–29). A 2008 household census conducted by the Desmond Tutu HIV Centre (unpublished data) estimated the resident population at 14,592, with 18.0%, 47.3%, and 34.7% of residents aged <15 years, 15–29 years, and >29 years, respectively (median age, 28 years).

Social mixing survey participant selection

Participants were randomly selected by age group (0–5, 6–11, 12–17, 18–23, 24–29, 30–40, or ≥41 years) from the census data by assigning each resident a randomly generated number in Excel (Microsoft Corporation, Seattle, Washington) and selecting residents in ascending order. The 738 selected township residents were visited at home over a period of 4 months in 2010 and invited to participate by community educators. The dwellings of unavailable residents were revisited on another day at a different time, to ensure maximum opportunity to engage with them. The maximum number of recruitment visits was 4. If a resident had emigrated since the census, a replacement was randomly selected from the same age group. Residents who chose not to participate or could not be contacted were not replaced. The census, conducted 2 years prior to the random selection, could not generate a list of participants under 3 years of age; therefore, the age group 0–5 years was selected from the children of randomly selected women of childbearing age (ages 15–45 years). Participants were given shopping vouchers valued at 75 South African rand as an incentive, and community educators were rewarded by the number of participants they enrolled who completed diaries.

Consent

The study was approved by the Human Research Ethics Committee of the University of Cape Town, and written informed consent was obtained from all participants. Parental/guardian consent was obtained for participants under 18 years of age, and signed assent forms were obtained from adolescents aged 12–17 years.

Diary survey

A paper diary (see Web Appendix 1, which appears on the Journal’s Web site (http://aje.oxfordjournals.org/)) in vernacular language was adapted from an earlier European study (30) to allow stratification of contacts by location. Participants completed the diary over a 24-hour period (5 AM–5 AM), after having received face-to-face coaching instruction. For participants under 11 years of age, parents/guardians completed the diary survey together with the child. All participants completed a face-to-face follow-up interview within 48 hours of diary completion to fill in missing data and clarify inconsistencies.

Participants recorded the types and names of locations visited within the assigned period, including whether the location was inside or outside the community and indoors or outdoors, as well as the duration of the visit, the time of day, and the number of social contacts met. Information was recorded for 2 classes of contacts, namely close contacts and casual contacts. Close contacts were defined as those involving physical touch (type I) or those involving a 2-way conversation with 3 or more words in the physical presence of another person without physical touch (type II). Casual contacts (type III) were defined as those occurring in an indoor location but not satisfying the criteria for a close contact. Participants recorded demographic data on close contacts met, whether physical touch was involved, whether it was the first time each close contact had been met within the 24-hour period, and the number of casual contacts present when indoors.

Data analysis

Data were entered into an Access database (Microsoft Corporation) and analyzed using STATISTICA 10.0 (StatSoft, Inc., Tulsa, Oklahoma). The numbers and ages of participants’ contacts were nonnormally distributed; therefore, Kruskal-Wallis analysis of variance by ranks, followed by multiple comparisons of mean ranks for all groups, was used for comparison of both median numbers and ages of contacts across baseline characteristics of study participants and day of diary completion. A Mann-Whitney U test was performed to compare median numbers of close contacts (types I + II) met per participant in this study and in the European study (30). All statistical tests were 2-sided at α = 0.05.

Midpoints between time-category limits were used to calculate the average contact time spent at a location. That is,
<table>
<thead>
<tr>
<th>Category</th>
<th>Total No. in Sample</th>
<th>Median No. (IQR) of Close Contacts</th>
<th>Median Age (IQR) of All Close Contacts, years</th>
<th>Median No. (IQR) of Indoor Contacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Type I (Physical)</td>
<td>Type II (Nonphysical)</td>
<td>Types I + II (All)</td>
</tr>
<tr>
<td>Total sample</td>
<td>571</td>
<td>12 (7–18)</td>
<td>9 (5–15)</td>
<td>20 (13–29)</td>
</tr>
<tr>
<td>Age group, years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–4</td>
<td>66</td>
<td>13 (9–17)</td>
<td>5 (3–8)</td>
<td>14 (10–22)</td>
</tr>
<tr>
<td>5–9</td>
<td>63</td>
<td>14 (9–20)</td>
<td>10 (4–12.5)</td>
<td>23 (16–32)</td>
</tr>
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<td>10–14</td>
<td>65</td>
<td>14 (10–22)</td>
<td>13 (7–19)</td>
<td>27 (18–39)</td>
</tr>
<tr>
<td>15–19</td>
<td>74</td>
<td>13 (8–21)</td>
<td>14 (7–22)</td>
<td>25.5 (18–38)</td>
</tr>
<tr>
<td>20–24</td>
<td>81</td>
<td>10 (6–16)</td>
<td>10 (7–15.5)</td>
<td>19 (12–29)</td>
</tr>
<tr>
<td>30–34</td>
<td>48</td>
<td>10.5 (8–18)</td>
<td>8 (5–12)</td>
<td>18.5 (12.5–27)</td>
</tr>
<tr>
<td>35–39</td>
<td>26</td>
<td>11.5 (9–18)</td>
<td>6 (3–11.5)</td>
<td>19 (12–26)</td>
</tr>
<tr>
<td>≥45</td>
<td>39</td>
<td>9 (4–13)</td>
<td>9 (4–13)</td>
<td>15 (10–21)</td>
</tr>
<tr>
<td>Gender</td>
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<td></td>
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</tr>
<tr>
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<td>293</td>
<td>12 (8–19)</td>
<td>10 (5–16)</td>
<td>21 (14–32)</td>
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<tr>
<td>Male</td>
<td>278</td>
<td>11 (7–17)</td>
<td>9 (5–13)</td>
<td>19 (13–27)</td>
</tr>
<tr>
<td>Employment status</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployed</td>
<td>152</td>
<td>9 (5–14)</td>
<td>9 (5–12)</td>
<td>17 (11.5–22.5)</td>
</tr>
<tr>
<td>Level of schooling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonattending</td>
<td>64</td>
<td>12 (8–15)</td>
<td>4.5 (3–8)</td>
<td>14 (10–19.5)</td>
</tr>
<tr>
<td>Cre`che</td>
<td>16</td>
<td>16 (13–26)</td>
<td>5 (4–7)</td>
<td>22.5 (14.5–28.5)</td>
</tr>
<tr>
<td>Secondary school</td>
<td>75</td>
<td>16.5 (10–24)</td>
<td>12 (6–22)</td>
<td>29 (20–38)</td>
</tr>
<tr>
<td>Tertiary education</td>
<td>5</td>
<td>12 (11–27)</td>
<td>8 (6–12.5)</td>
<td>26 (20–33)</td>
</tr>
<tr>
<td>P value</td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 1. Median Number of Close Contacts per Participant, Median Age of Close Contacts, and Median Number of Indoor Contacts per Participant, According to Baseline Demographic Data on 571 Randomly Selected Residents of a South African Township Community, 2010.
### Simulating the initial spread of an influenza epidemic

The age-specific number of new infections was modeled for an influenza strain introduced into a completely susceptible population similar to the study community and spread by either physical touch or large respiratory droplets (i.e., physical or close contacts). Tuberculosis transmission by droplet nuclei (i.e., all indoor contacts) was not modeled, since the ages of casual contacts were not recorded by participants and consequently an age-structured model for this mode of transmission could not be constructed.

The “social contact hypothesis” states that the number of age-specific newly infected cases is proportional to the number of age-specific social contacts, with a proportionality constant, $q$, indicating the disease-specific infectivity (probability of infection per social contact) (31). This is reasonable because spatial proximity of social contacts acts as a proxy to that required for exposure to infection. Wallinga et al. (31) estimated $q = 0.036$ for an Asian influenza outbreak using age-specific numbers of weekly conversational contacts, and this is therefore applicable to close-contact transmission as defined here (types I + II). Correcting for the fact that weekly, not daily, contacts were used (see Web Appendix 2), we estimated $q = 0.252$. Corresponding values for physical contact (type I) transmission have not been reported. Consequently, we performed sensitivity analysis for physical touch, varying $q$ from 0.252 to 0.756 (relative risk = 1–3), since physical touch is more likely to result in transmission than close contact. Two other assumptions of this model include that individuals are contacted randomly within age groups and that the aging of hosts can be ignored because the duration of influenza virus infection is much shorter than the life span of human hosts.

The age-structured model was constructed by partitioning the population under 45 years of age into nine 5-year age groups, with a tenth group for those aged 45 years or older. The number of newly infected individuals per infectious case was characterized by the “next generation matrix” $N = (n_{jk}) = (qm_{jk})$, where $m_{jk}$ corresponded to the mean number of individuals from age group $j$ a participant in age group $k$ interacted with (through physical or close contact) in a single day (see Web Table 1). The number of individuals a participant met each day was determined from those diary contacts recorded as having been met for the “first time today.” This prevented individuals from being infected multiple times in a single generation of infection, so that the number of newly infected cases was not overestimated.

The number of infections $i$ generations after disease introduction, $x_i$, was iteratively calculated from $x_i = Nx_{i-1} = N^ix_0$, where $x_0$ is the 0th generation of infectious cases. The initial infectious case was assumed to be a person 25–29 years of age, such that $x_0 = [0,0,0,0,0,0,1,0,0,0]^T$, since people in this age group made use of transport (predominantly minibus taxis) most frequently and were therefore most likely to bring infection into the community.

Matrix theory governs that for large values of $i$ (in practice, from the fifth generation onwards), the age distribution of
newly infected cases is independent of the initial case and proportional to the leading eigenvector of $N$. Furthermore, the leading eigenvalue is equivalent to the basic reproductive number, $R_0$, which describes the average number of secondary cases produced by an infectious case when introduced into a completely susceptible population. Consequently, we determined the characteristic age distribution of newly infected cases in the fifth generation of infection, along with the basic reproductive number, for influenza transmitted by physical and close contact.

**RESULTS**

**Sampled population characteristics**

Of 738 randomly selected residents, 86 were replaced (census address no longer existed, resident corresponding to census demographics was not known at address, resident had moved out of community since census, or woman had no child under 5 years of age) and 39 were not replaced (close not to participate or could not be contacted or replaced within the study period). Of the 699 residents who consented to participate, the diaries of 106 were excluded from analysis because of concerns that 1 educator had completed the diaries instead of the participants. Of the 593 remaining participants, 10 subsequently withdrew, 4 were lost to follow-up, and 8 did not return completed diaries.

Baseline characteristics of the 571 study participants who completed diaries, along with the day of diary completion, are shown in Table 1. Of these participants, 34.0%, 38.0%, and 28.0% were aged <15 years, 15–29 years, and >29 years, respectively.

**Number of reported contacts**

The number and duration of 571 participants’ contacts were categorized into close (types I + II) or casual (type III), within or outside of the study community, and indoors or outdoors (Figure 1). Participants reported 29,125 contacts, of which 12,946 (44.4%) were close and 16,179 (55.6%) were casual. Of close contacts, 10,633 (82.1%) occurred within the community and 7,903 (61.0%) involved physical touch (type I). A total of 6,455 (81.7%) physical contacts took place within the community. Casual contacts (type III) accounted for 16,179 (64.5%) of all indoor contacts, with 7,465 (46.1%) occurring within the community.

**Close and physical contacts**

The median number of close contacts (types I + II) per participant was associated with participant age, gender, employment status, level of schooling, and day of diary completion, with participants aged 10–14 years recording the most indoor contacts at 43 per day (Table 1). In particular, the median age of close contacts was significantly lower on Saturdays than on Mondays and Fridays ($P = 0.04$ and $P = 0.003$, respectively), possibly because 59.3% of casual contacts were met during travel and when children were at crèche/school midweek (Table 2).

**Indoor contacts**

The median number of indoor contacts (types I + II + III) per participant was associated with participant age, gender, employment status, level of schooling, and day of diary completion, with participants aged 10–14 years recording the most indoor contacts at 43 per day (Table 1). Numbers of indoor casual contacts (type III) were significantly lower on Saturdays than on Mondays and Fridays ($P = 0.04$ and $P = 0.003$, respectively), possibly because 59.3% of casual contacts were met during travel and when children were at crèche/school midweek (Table 2).

**Location of close, physical, and indoor contacts**

Most close (types I + II) and physical (type I) contacts occurred at 6 locations: contacts occurring within the participant’s own household, in the participant’s neighborhood (outside household environs and streets), at crèche/school, during transport, in other households, and at work accounted for 33.6%, 23.5%, 12.8%, 8.9%, 7.1%, and 6.2% of close contacts and 36.3%, 22.0%, 11.6%, 10.2%, 6.3%, and 6.0% of physical contacts, respectively (Table 2). Similarly, 95.3% of indoor contacts (types I + II + III) were recorded at 7 locations: during transport (27.2%), in one’s own household (20.1%), at crèche/school (20.0%), in shops (8.9%), at work (8.0%), in community buildings (6.0%), and in other households (5.0%).

**Duration of indoor contacts**

Indoor contact time was predominantly spent in 5 congregate settings, with 80.0%, 5.0%, 4.9%, 4.9%, and 2.3% of the time spent in participants’ own households, at crèche/school, at work, in other households, and in transport, for average durations of 15.2 hours, 4.1 hours, 6.4 hours, 2.3 hours, and 1.4 hours, respectively. Prolonged contacts over 4 hours in length were reported in 73.9%, 47.3%, and 38.3% of visits to work, own household, and crèche/school, respectively, but in only 7.9% of visits to other households. The contact period was shortest for transport, with 98.1% of contacts lasting under 4 hours. Figure 2 shows the mean number of indoor contacts met daily per participant within these congregate settings, stratified by 5-year participant age group and contact type.

**Influenza epidemic simulation**

The number of new infections in the fifth generation of an influenza epidemic was simulated (Figure 3).
will occur among persons aged 15–19 years and 25–29 years for both physical and close-contact transmission (Figure 3, parts A and B), highlighting the increased social interaction in these age groups and the consequential increased exposure to infectious diseases they face. The proportion of infections occurring in young children (under 9 years of age) and in adults 30–44 years of age is greater for physical transmission than for close contact, and consequently epidemics spread by physical touch will be more widespread across age groups. Sensitivity analysis showed that the number of new infections by physical touch was highly dependent on the transmission probability per social contact, with 14 and 3,533 newly infected individuals aged 15–19 years when $q = 0.252$ and $q = 0.756$, respectively. It also revealed that the basic reproductive number was directly proportional to $q$, with $R_0 = 2.48$, $R_0 = 4.96$, and $R_0 = 7.44$ when $q = 0.252$, $q = 0.504$, and $q = 0.756$, respectively. $R_0$ was estimated at 4.15 for transmission by close contact.

**DISCUSSION**

We have described the social mixing patterns of a South African township population. The analyses focused on social contacts (physical, close, and indoor) relevant to 3 major pathways (physical touch, large droplets, and droplet nuclei) for respiratory disease transmission (10, 17, 20). The number and age distribution of contacts and the transmission probability per contact affected the number and age distribution of new infections simulated for an influenza epidemic in the township community.

Physical contacts (type I) accounted for 27.1% of all contacts. The mean number and proportion of age-associative physical contacts peaked among youths aged 5–19 years, steadily decreasing as participant age increased. Younger age groups would therefore be most heavily affected in epidemics spread by physical touch. Simulations confirmed this, with the rate of the new infections highest among adolescents.
Table 2. Numbers of Close and Indoor Contacts Recorded During a 24-Hour Period by 571 Randomly Selected Participants From a South African Township Community, According to Location and Type of Contact, 2010

<table>
<thead>
<tr>
<th>Location</th>
<th>Close Contacts</th>
<th>Indoor Contacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type I (Physical)</td>
<td>Type II (Nonphysical)</td>
</tr>
<tr>
<td>Community building</td>
<td>206</td>
<td>73</td>
</tr>
<tr>
<td>Crèche/school</td>
<td>920</td>
<td>651</td>
</tr>
<tr>
<td>Health clinic</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Neighborhooda</td>
<td>1,737</td>
<td>1,260</td>
</tr>
<tr>
<td>Own household</td>
<td>2,868</td>
<td>1,420</td>
</tr>
<tr>
<td>Other households</td>
<td>498</td>
<td>404</td>
</tr>
<tr>
<td>Local “shebeen” bar</td>
<td>78</td>
<td>83</td>
</tr>
<tr>
<td>Shop</td>
<td>181</td>
<td>106</td>
</tr>
<tr>
<td>Sports venue</td>
<td>69</td>
<td>52</td>
</tr>
<tr>
<td>Transport</td>
<td>803</td>
<td>326</td>
</tr>
<tr>
<td>Work</td>
<td>474</td>
<td>320</td>
</tr>
<tr>
<td>Other miscellaneous sites</td>
<td>54</td>
<td>74</td>
</tr>
<tr>
<td>Total</td>
<td>7,903</td>
<td>4,781</td>
</tr>
</tbody>
</table>

*a* Outside household environs and streets.

Figure 2. Mean number of indoor contacts (types I + II + III) per participant recorded during a 24-hour period A) in all households (participants’ own households and other households), B) at crèche/school, C) at work, and D) during transport (predominantly minibus taxis), by 5-year participant age group and contact type, in a South African township community, 2010. Average durations of indoor contact in participants’ own households, in other households, at crèche/school, at work, and during travel were 15.2 hours, 2.3 hours, 4.1 hours, 6.4 hours, and 1.4 hours, respectively, with prolonged contacts lasting over 4 hours reported for 47.3%, 7.9%, 38.3%, 73.9%, and 1.9% of visits to each location.
The frequency of close contact (types I + II) is thought to be a major determinant of the spread of diseases transmitted by large respiratory droplets (10, 11). Close contacts contributed 44.4% of all contacts and were most frequent and age-associative among youths aged 10–19 years. Simulations confirmed that the greatest number of infections would occur within these age strata. Of particular significance was the fact that the number of individuals met (i.e., “first time today” close contacts) was 40% higher in this township than that reported for European populations (median of 14 vs. 10; \( P < 0.001 \)) (30). This suggests that influenza epidemics, transmitted by close contact, may affect this community more than European populations. We also note that the locations where close contacts were recorded were similar to those of the European study, but the proportion of contacts met at each location was significantly different \( (\chi^2 \text{ test: } P < 0.001) \).

Social distancing strategies such as individual quarantine, school closure, and banning of public gatherings, previously applied with some success, may need to be tailored to the community (32). However, social distancing strategies and vaccination should particularly target adolescents (33).

Where tuberculosis is endemic, such as in the study community (27–29), transmission is determined by the number of exposures to infectious cases, time of exposure, and the volume and ventilation characteristics of the shared enclosed space (22–24). Indoor contacts (types I + II + III) were the most common type of social mixing, accounting for 86.2% of all contacts and occurring both within (58.4%) and outside (41.6%) the township. The high numbers of these contacts may therefore be contributing to the high tuberculosis rates seen in this community (8, 27–29, 34). Indoor contacts were also noted as being predominantly limited to a few key locations. Intergenerational mixing was most frequent in households and during transport, with long exposure times in households but short exposure times during travel. Contact times at crèche/school and at work were long, but contacts made there were marked age-associative. Therefore, prolonged social interactions between adults and young children occurred predominantly within households. This is consistent with reports of high household transmission from smear-positive adults to young children within this community (24, 29). Numbers of nonhousehold indoor contacts increased rapidly during adolescence, increasing their potential for exposure to infectious adults, which in turn may be contributing to the increasing rates of tuberculosis infection observed in these age groups (9, 35).

Another significant finding for endemic tuberculosis transmission was that high numbers of contacts take place during transport. In a study conducted in Peru, use of public transportation was associated with increased incidence of tuberculosis (36, 37). However, because exposure time during travel was short (mean travel time of 1.4 hours), tuberculosis transmission would be sensitive to ventilation during transport (24). High use of public transportation and high potential for respiratory disease transmission warrant further studies of tuberculosis transmission within public transportation systems in South Africa.

To our knowledge, this study was the first to explore social interactions relevant to the spread of respiratory disease in an African population and one of the few using social mixing data to model the spread of a respiratory disease (30, 31, 38). Participants were randomly selected from a South African township; therefore, the findings may be generalized to similar newly urbanized communities. Two important features of the study were the modification of the European diary to include casual contacts, relevant to the indoor spread of respiratory diseases by droplet nuclei, and the face-to-face interviews with participants after diary completion to ensure data integrity and entirety. Study limitations included the fact that the mode of influenza transmission can vary between strains. Our analysis assumed that influenza is spread predominantly by physical or close contact (12). Therefore, values used for \( q \) may only be applicable to the Asian influenza strain considered by Wallinga et al. (31). Another aspect of the study to be reconsidered in future research was participants’ not recording the ages of casual contacts. Large numbers of casual contacts were expected in certain locations (e.g., shops), so the recording of casual-contact demographic data would be difficult in a diary format. Novel approaches should address...
REFERENCES


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