INTRODUCTION

Japan started the HIV/AIDS surveillance program in 1984 (1). Under the surveillance system, if an HIV infection was detected before the development of an indicator disease of AIDS, it was registered as “HIV”; if the infection was detected after the development of an indicator disease, the case was registered as “AIDS”. Once notified as “HIV”, the case would remain registered as “HIV” even if the patient later developed an AIDS indicator disease. The legal background and other information on HIV/AIDS surveillance are available in (2,3), and the notification criteria are available in (4).

By 2012, a total of 14,706 “HIV” and 6,719 “AIDS” cases were reported in Japan. Among them, 82% of “HIV” and 83% of “AIDS” patients were of Japanese nationality. Among patients of Japanese nationality, 64% of “HIV” acquired infection through homosexual contact, 25% through heterosexual contact; 58% of “AIDS” acquired infection through homosexual contact and 37% through heterosexual contact. The infection route was unknown in 8% of “HIV” and 19% of “AIDS” cases. Infection through intravenous drug injections or mother-to-child transmission was negligibly small in proportion (3).

This paper deals with the geo-demographic aspects of HIV/AIDS. Where data are available, data were compared between Japan and the United States of America (USA).

MATERIALS AND METHODS

Data used in the present analysis are derived from the national AIDS Surveillance Committee, Ministry of Health, Labour and Welfare (2012): Trends of AIDS in Japan started the HIV/AIDS surveillance program in 1984 (1). Under the surveillance system, if an HIV infection was detected before the development of an indicator disease of AIDS, it was registered as “HIV”; if the infection was detected after the development of an indicator disease, the case was registered as “AIDS”. Once notified as “HIV”, the case would remain registered as “HIV” even if the patient later developed an AIDS indicator disease. The legal background and other information on HIV/AIDS surveillance are available in (2,3), and the notification criteria are available in (4).

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This paper deals with the geo-demographic aspects of HIV/AIDS. Where data are available, data were compared between Japan and the United States of America (USA).
### Fig. 1. Cumulative frequency distribution of population size and HIV/AIDS in various prefectures or states (distinct). Panel A: Japan: horizontal axis (logarithmic scale): population size ($\times 1,000$) / prefecture ($\triangle$); number of patients for “HIV” ($\bigcirc$) and “AIDS” in 1985–2011 ($\bullet$); syphilis in 2009–2011 ($\square$); tuberculosis in 2011 ($\bigtriangleup$). Vertical axis (normal scale): cumulative number of prefectures or ranking number counting from the smallest. “Population data” was obtained from <http://www.stat.go.jp/data/nihon/02.htm>. Panel B: USA: horizontal axis (logarithmic scale): population size / state in 2010 ($\triangle$), and number of “AIDS diagnosis” in 2009 ($\bigcirc$). Vertical axis (normal scale): cumulative number of prefectures counting from the smallest or ranking number from the smallest. “AIDS diagnosis” data was obtained from Table 20, available at <http://www.cdc.gov/hiv/pdf/statistics_2009_HIV_Surveillance_Report_vol21.pdf>. “Population data” was obtained from <http://en.wikipedia.org/wiki/Demographics_of_the_United_States>.

The frequency distribution of tuberculosis cases was $\sim 1.3 \log$. Panel B of Fig. 1 shows the frequency distribution of the patients “diagnosed as AIDS” in the USA, whose width was $\sim 2.8 \log$. The ratio of the width of the frequency distribution of “HIV” or “AIDS” cases relative to that of the population size was $\sim 1.5$ for both Japan (2 divided by 1.3) and the USA (2.8 divided by 1.9). The ratio for syphilis cases was also $\sim 1.5$. For tuberculosis cases, it was $\sim 1$. The frequency distribution of HIV/AIDS cases was $\sim 1.5$ times wider than that of the population size in both Japan and the USA, but that of tuberculosis cases was the same as that of the population size.

**Relation between number of HIV/AIDS patients and population size:** In Fig. 2, the number of patients ($P$) is plotted on the vertical axis, and the population size of prefectures/states ($\times 1,000$) ($N$) is plotted on the horizontal axis. The plots were approximated by the power approximation in an Excel file (straight lines in the figures). The relation between $P$ and $N$ could be expressed approximately as $P = kN^m$ or $\log P = m \log N + \log k$. The coefficient $m$ of $\log N$ is the slope of the log–log plot. The slope was $1.52$ for “AIDS” in Japan (panel B) and $1.34$ for “AIDS diagnosis” in the USA (panel D). For “HIV” in Japan, the slope was $1.63$ (panel A), and for syphilis, it was $1.38$ (panel C). For tuberculosis, the slope was $1.01$ (panel C in Fig. 2). For other infections, it was previously found that, while it was $\sim 2$ for measles and rubella, it was $\sim 1$ for most of the infections examined, such as gastroenteritis; erythema infectiosum; influenza; hand, foot and mouth disease; Group A streptococcal pharyngitis; and mycoplasma pneumonia (5). The slope of the plots for “HIV” or “AIDS” remained essentially unchanged from 1985 to 2011 (panels A and B, respectively, in Fig. 3). Thus, the slope $m$ was found to be stable over time and was within a narrow range for “AIDS” in Japan ($\sim 1.5$) and “AIDS diagnosis” in the USA ($\sim 1.3$).

Extrapolation of the plots in Fig. 2 to the horizontal axis provides a minimum population size of a community with at least one HIV/AIDS patient per community. (Note that the coordinates of horizontal axis where the extrapolation of the plots crosses the horizontal axis, $N_0$ for $P = kN^m$ and $D_0$ for $I = hD^n$, are the function of $k$ or $h$, because they can be expressed as $N_0 = [1/k]^{1/m}$.
Fig. 2. Relation between number of patients and population size.
Panels A–C: Japan: horizontal axis: population (×1,000)/prefecture; vertical axis: number of “HIV” (panel A); number of “AIDS” (panel B); number of syphilis in 2009–2011 and tuberculosis in 2011 in Japan (panel C). Prefectures in the Kanto-Koshinetsu area are circled. Panel D: USA: horizontal axis: population size/state; vertical axis: number of “AIDS diagnosis” in 2009. Dotted lines are straight line with slope 1. For Japan, data on HIV/AIDS was obtained from <http://api-net.jfap.or.jp/status/2012/12nenpo/nenpo_menu.htm>, and data on other infectious diseases from <http://www.nih.go.jp/niid/ja/all-surveillance/2270-idwr/nenpou/3359-syulist2011.html>. For the USA, the data was obtained as shown in Fig. 1.

Fig. 4. Relation between number of incidence (patients / population) and population density. Data was obtained from [http://www.stat.go.jp/data/nenkan/02.htm](http://www.stat.go.jp/data/nenkan/02.htm). Panel A: vertical axis: “HIV” (○) and “AIDS” (●) incidences (total number of patients/100,000 population) in Japan from 1985 to 2011. Horizontal axis: population density (population [× 10]/km² in 2010). Panel B: vertical axis: incidence (patients/100,000 population) of syphilis in Japan in 2009–2011 (■) and tuberculosis in 2011 (△); horizontal axis: population density (population [× 10]/km² in 2010). Panel C: vertical axis: “AIDS diagnosis” in the USA/100,000 population in 2009. Horizontal axis: population density (population/mi² in 2010) (the web page of U.S. Census Bureau, Statistical Abstract of the United States 2012). Correlation coefficients (CCs) between incidence and population density for “HIV”, “AIDS”, syphilis, and tuberculosis among 47 prefectures in Japan were 0.824, 0.616, 0.566, and 0.206, respectively; that for “AIDS diagnosis” among 51 states (distinct) in the USA was 0.953.

and D₀ = [1/h]). For example, the extrapolation of the plots in panel A of Fig. 2 crosses at N ~140,000; therefore, the minimum community size to have at least one “HIV” patient from 1985 to 2011 in Japan was ~140,000. Similarly, for “AIDS”, it was ~160,000 (panel B). For “AIDS diagnosis” in the USA in 2008 (panel D), similarly, the minimum community size was ~60,000. In Fig. 3, the plots for 1985–1997, 1998–2004, and 2005–2011 crossed the horizontal axis at N ~500,000, ~400,000, and ~200,000, respectively; these values are the expected minimum size of a community with at least one “HIV” patient. It was suggested that, in Japan, the HIV/AIDS epidemic started in communities larger than ~500,000 in 1985–1997 and then extended gradually to smaller communities.

Relation between HIV/AIDS patient incidence and population density: In panel A of Fig. 4, the numbers of “HIV” (○) or “AIDS” (●) cases /100,000 population (i.e., incidence) are plotted on the vertical axis against population density (population [× 10]/km²) on the horizontal axis for 47 prefectures in Japan. The slopes for “HIV” and “AIDS” were 0.58 and 0.38, respectively. The slope of 0.38 for “AIDS” in Japan was identical to that of “AIDS diagnosis” in the USA (6) (panel C of Fig. 4) that had been shown previously (7). A slope > 0 in this type of plot indicates that as population density increases, disease incidence increases disproportionately. Panel B shows similar plots for syphilis in 2009–2011 (■) and tuberculosis in 2011 (△) in Japan. The slopes are 0.27 and 0.06, respectively. While syphilis showed population density dependency similar to HIV/AIDS, tuberculosis did not.

The data presented in this section can be summarized as follows: i) number of patients P and population size N are correlated with an equation P = kN^m where k and m are constants. The constant m for “AIDS” in Japan and that for “AIDS diagnosis” in the USA were within a narrow range (1.52 and 1.33, respectively). For syphi-
Fig. 5. Graphics for demonstrating dependency of “AIDS” incidence both on population size and density. Panel A: graphics for examining impact of population size/density on AIDS incidence. Vertical axis: population density (number of people/km²) of a prefecture. Horizontal axis: population size (×1,000) of a prefecture. Circle size reflects incidence of “AIDS” (number of patients/100,000 prefecture population) (see Fig. 5B for the derivation). Panel B: cumulative frequency distribution of “AIDS” incidence (number of “AIDS”/100,000 population)/prefecture, which follows near-log normal distribution. The distribution range was 2.4–2.8 log 10 for the three periods. The distribution range was divided into 4 in the manner as shown in the bottom of the graph (the data used were for year 2005). These circles were used for the plots of prefectures in A. Panel C: map of Japan (derived from http://kappanosara.jimdo.com/word/map-japan/). Areas are indicated by bold letters and prefectures by ordinary letters. The number after the area or prefecture name indicates the prefecture number used in Fig. 6.

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lis, it was 1.38, and for tuberculosis, it was 1.01; ii) incidence I and population density D were correlated with an equation \( I = hD^n \), where \( h \) and \( n \) are constants. The constant \( n \) was 0.38 for both “AIDS” in Japan and “AIDS diagnosis” in the USA. It was 0.58 for “HIV” in Japan, 0.27 for syphilis, and 0.06 for tuberculosis. Thus, the HIV/AIDS epidemics in both Japan and the USA could be expressed by the same mathematical formulae relating patient number to population size and patient incidence to population density. The constants \( m \) and \( n \) could be universal parameters of the HIV/AIDS epidemic.

Graphics showing dependency of HIV/AIDS epidemic on both population size and density: Fig. 5A shows the graph matrix of population density (× km²) on the vertical axis and population size (×1,000/prefecture) on the horizontal axis, on which 47 prefectures are plotted. Each prefecture is represented by a circle whose size corresponds to the incidence range of the prefecture. The larger circles (i.e., prefectures with high incidence) are clustered in the upper right corner, and the smaller ones are clustered in the lower left; the incidence of “AIDS” was high in prefectures with a larger population size and higher population density.

Fig. 5B shows the graphics demonstrating how the circle sizes were determined. It is a cumulative frequency distribution of “AIDS” incidence (number of “AIDS” cases/100,000 population)/prefecture. The distribution was near lognormal, and the range was 2.4–2.8 log 10 for 1985–1997, 1998–2004, and 2005–2011 periods. The total range was divided into four incidence ranges (1, 2, 3, and 4) at an equal distance as shown by the scale at the bottom (an example using the 2005–2011 data). The incidence ranges 1, 2, 3, and 4 were represented by each sized-circle shown at the bottom of this figure.

A similar pattern is expected for “HIV” as the correlation coefficients between “AIDS” and “HIV” among
Fig. 6. Accumulation of “HIV” and “AIDS” in different prefectures in Japan since 1985. Panel A: “HIV”; panel B: “AIDS”. Vertical axis: number of patients in the logarithmic scale; horizontal axis: numbering of prefectures starting from Hokkaido to Okinawa (see the top of the panel A). The smallest, the medium sized, and the largest symbols indicate number of patients in 1985–1997, 1985–2004, and 1985–2011, respectively.

Distribution of HIV/AIDS in different prefectures: Fig. 6 shows the distribution of “HIV” (panel A) and “AIDS” (panel B) in 47 prefectures in Japan. The numbers in the horizontal axis represent prefectures numbered from the north to the south; prefectures with adjacent numbers are geographically close. The prefectures are grouped into 7 areas: prefectures 1–7 in the Hokkaido-Tohoku area, number 8–17 in the Kanto-Koshinetsu area (Tokyo, number 13, is often treated separately), number 18–21 in the Tokai area, number 22–24 in the Hokuriku area, number 25–30 in the Kinki area, number 31–39 in the Chugoku-Shikoku area, and number 40–47 in the Kyushu area (Fig. 5C and the top of Fig. 6A). The logarithm of number of patients is plotted on the vertical axis; small, medium, and large symbols represent the total number of the patients accumulated from 1985 to 1997, to 2004, and to 2011, respectively.

The plot pattern was almost identical for “HIV” and “AIDS”. Prefectures with high “HIV” (panel A) or “AIDS” (panel B) were 13 (Tokyo), 21 (Aichi), 27 (Osaka), and 40 (Fukuoka); 8, 9, 11, 12, and 14 are prefectures close to Tokyo, 19 is near both Tokyo and Aichi, and 26 and 28 are near Osaka. Tokyo, Aichi, Osaka, and Fukuoka are the most highly populated prefectures in Japan.

Different HIV/AIDS epidemiology among prefectures in Japan: This section compares various prefectures in Japan with respect to modes of HIV/AIDS detection and transmission.

The method presented here could be used for other epidemics that could be influenced by population size/density (5), such as, measles, rubella, and syphilis. Fig. 5C shows the location of areas including prefectures in Japan (see the top and the bottom of panel A of Fig. 6 for areas to which prefectures 1–47 belong).

HIV/AIDS epidemic by area and by prefecture in Japan: This section compares various prefectures in Japan with respect to modes of HIV/AIDS detection and transmission.
Fig. 7. Relative frequency of homosexual men to men infections (vertical axis) vs. heterosexual men infections (horizontal axis) for patients detected as “HIV” (panel A) and for those detected as “AIDS” (panel B). Horizontal and vertical axes indicate number of patients infected through heterosexual and number of patients infected through homosexual routes, respectively. The broken line in each panel is the straight line with slope 1 that crosses the origin of the coordinates. The plots were approximated by the “polynomial approximation method” in the Excel file.

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than for “AIDS” irrespective of areas (compare plots in panels A and B for the same areas); for patients detected as “HIV” (panel A) compared with those detected as “AIDS” (panel B), transmission through the homosexual route (vertical axis) was more frequent than that through the heterosexual route (horizontal axis); iii) there was a large variability among areas with respect to the ratio of heterosexual transmission to homosexual transmission. In Tokyo (□), Kinki (●), Tokai (■), and Kyushu (●) areas, the transmission route was dominantly homosexual. In Kanto-Koshinetsu area (excluding Tokyo) (▲), however, heterosexual transmission was comparable or even dominant (see Kanto-Koshinetsu in panels A and B).

In Fig. 8, the number of heterosexual men is plotted on the horizontal axis, and that of heterosexual women is plotted on the vertical axis for patients detected as “HIV” (panel A) or those detected as “AIDS” (panel B). Differing from the plot of heterosexual vs. homosexual men, the plot followed a near straight line reflecting the fact that women are infected always heterosexually. The slope of the plots was flat (1/6 ~ 1/3 for HIV and ~1/8 for AIDS), indicating that the population of heterosexual men is far dominant over the heterosexual women. It may indicate multiple sex partnership in female HIV/AIDS patients (compare Fig. 8 with Fig. 7).

Assessing transmission routes at the prefecture level: In the above analysis, it was found that heterosexual transmission was more prevalent in the Kanto-Koshinetsu area than in other areas, which was intriguing as Tokyo belongs to the Kanto-Koshinetsu area, and homosexual transmission was prevalent in Tokyo. To advance the analysis, information on the prefecture level is needed. Currently, however, the data available at the prefecture level are only detection as “HIV” or as “AIDS”.

In the analysis below, the ratio of “AIDS” to “HIV” was used as a surrogate for assessing the relative dominance of heterosexual vs. homosexual individuals because the ratio of detection as “HIV” to detection as “AIDS” was previously found to be higher for homosexual than for heterosexual individuals (8). Suitability of the approach was checked by the following two methods: Method I, in Fig. 9, “AIDS” is plotted on the vertical axis, and “HIV” is plotted on the horizontal axis for Japanese patients in the Kanto-
Fig. 8. Relative frequency of women (vertical axis) vs. heterosexual men (horizontal axis) for “HIV” (panel A) and “AIDS” (panel B) in each areas. The broken line in each panel is the straight line with slope 1 that crosses the origin of the coordinates.

Koshinetsu area (Fig. 9A) and in Tokyo (Fig. 9B). The slopes of heterosexual men, homosexual men, and the total (heterosexual men + homosexual men + women) were 1.0, 0.47, and 0.70, respectively, for Kanto-Koshinetsu (excluding Tokyo) and 0.58, 0.23, and 0.29, respectively, for Tokyo. The plots of the total were sandwiched between the plots of heterosexual and homosexual men, and the slope of the total was largely determined by whether homosexual or heterosexual men made up majority; for example, for Tokyo, 0.70 for the total was closer to 1.0 for homosexual men than to 0.47 for heterosexual men, and for Kanto-Koshinetsu, 0.29 for the total was closer to 0.23 for heterosexual men than to 0.58 for homosexual men. Thus, it was expected that, the higher the ratio of “AIDS” to “HIV”, the higher the ratio of “heterosexual men” to “homosexual men”. Method II, detection types and infection routes were tabulated for each area as shown in Table 1, and the correlation coefficients (CCs) were calculated for various pairs of parameters. The CC between the ratio of “AIDS” to “HIV” (AIDS/HIV) and the ratio of heterosexual individuals to homosexual individuals (hetero/homo) was 0.77; they were significantly correlated. The above two analyses indicated that the ratio of “AIDS” to “HIV” could be used as a surrogate for assessing the transmission routes.

In Fig. 10, the prefectures are plotted on the matrix with the number (from 1985 to 2011) of “HIV” on the horizontal axis and the number of “AIDS” on the vertical axes. For both Japanese (panel A-1) and non-Japanese (panel B-1) patients in Japan, prefectures with lower numbers of patients were clustered around the line expected for a 1:1 ratio of “HIV” to “AIDS” (broken line with slope of 45°), but prefectures with larger numbers of patients were found far below the line. The same tendency was observed for the USA (panel C-1). In order to magnify the distribution of plots near the origin of the coordinates, in panels A-2 (for Japanese), B-2 (for non-Japanese), and C-2 (for the USA), the ratio of “AIDS” to “HIV” was plotted on the vertical axis, and the number of “HIV” cases was plotted on the horizontal axis. It was found that the “AIDS”/”HIV” ratio decreased as the number of “HIV” cases increased. It was therefore inferred that, at least for Japan, homosexual transmission was more predominant in the prefectures with higher numbers of “HIV” patients, which are more populated prefectures (Fig. 2). In the USA as well, detection as “HIV” was higher in populated states with large numbers of “HIV” cases.

The variable dominance of homosexual vs. heterosexual individuals among the different areas observed in Fig. 6 and in Table 1 was probably determined by the presence or absence of prefectures with extra-high numbers of “HIV” cases; Aichi prefecture in the Tokai area accounted for 59% of the total HIV/AIDS cases in the area, Osaka prefecture in the Kinki area accounted for 72% of the total HIV/AIDS cases in the area, and Fukuoka...
Table 1. HIV/AIDS epidemic among Japanese population from 1985 to 2011 in Japan by area

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<tbody>
<tr>
<td>Hokkaido-Tohoku</td>
<td>17,500</td>
<td>339</td>
<td>196</td>
<td>0.58</td>
<td>291</td>
<td>192</td>
<td>52</td>
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<td>Kanto-Koshinetsu</td>
<td>33,949</td>
<td>1,772</td>
<td>1,138</td>
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<td>1,196</td>
<td>1,412</td>
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<td>0.29</td>
<td>3,873</td>
<td>1,072</td>
<td>232</td>
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<td>434</td>
<td>0.50</td>
<td>891</td>
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<td>37</td>
<td>0.44</td>
<td>66</td>
<td>46</td>
<td>9</td>
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<tr>
<td>Kinki</td>
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<td>1,838</td>
<td>601</td>
<td>0.33</td>
<td>1,840</td>
<td>526</td>
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<td>Chugoku-Shikoku</td>
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<td>155</td>
<td>0.42</td>
<td>323</td>
<td>171</td>
<td>28</td>
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<td>Kyushu</td>
<td>14,764</td>
<td>573</td>
<td>280</td>
<td>0.49</td>
<td>578</td>
<td>222</td>
<td>53</td>
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<td>3,990</td>
<td>0.40</td>
<td>9,058</td>
<td>3,977</td>
<td>831</td>
</tr>
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\(^{1)}\): AID/HIV: number of “AIDS” divided by “HIV”; homo: homosexual transmission; hetero: heterosexual transmission; hetero/homo: number of heterosexual transmission divided by the number of homosexual transmission. This table does not contain data for non-Japanese population in Japan and data for transmissions other than sexual routes. Kanto-Koshinetsu means Kanto-Koshinetsu area excluding Tokyo.

\(^{2)}\): CC between AIDS/HIV and hetero/homo = 0.77. \(^{3)}\): CC between heterosexual and homosexual men = 0.95.

\(^{4)}\): CC between women and homosexual men = 0.63. \(^{5)}\): CC between women and heterosexual men = 0.98.
Fig. 10. Detection as “HIV” vs. as “AIDS” in 47 prefectures in Japan and 51 states (distinct) in the USA. Panels A-1, B-1, and C-1: number of “AIDS” (vertical axis) vs. number of “HIV” (horizontal axis) for Japanese (A-1) and non-Japanese (B-1) in Japan, and for the USA (C-1). Each dot represents a prefecture in Japan or a state (distinct) in the USA. Prefectures in Kanto-Koshinetsu area are enclosed in larger symbols. Panels A-2, B-2, and C-2: AIDS/HIV ratio (vertical axis) vs. number of “HIV” (horizontal axis) for Japanese (A-2) and non-Japanese (B-2) in Japan, and for the USA (C-2). Prefectures in Kanto-Koshinetsu area are enclosed in larger symbols. The approximation line was obtained by log approximation on the Excel file. Data for the USA were derived from Tables 19 and 20 of http://www.cdc.gov/hiv/pdf/statistics_2009_HIV_Surveillance_Report_vol_21.pdf. “HIV” was obtained by subtracting “AIDS diagnosis” from “diagnosis of HIV infection” that includes persons with a diagnosis of HIV infection regardless of stage of diseases at diagnosis. Dotted lines are straight lines with slope 1.

cases. However, it accounted for only 29% of the total “HIV” cases in the area.

It is interesting to note that there was a high degree of correlation (CC = 0.95) between heterosexual transmission and homosexual transmission among the seven areas and Tokyo (see the bottom of Table 1 marked by 3). This may indicate that heterosexual and homosexual transmissions share the same social environment. Age distribution among prefectures: HIV is transmitted sexually, and the sexual activity is influenced by age. Homosexual individuals were generally found to be younger than heterosexual individuals among both “HIV” and “AIDS” (Fig. 11, panels A-1 and A-2).

Fig. 11B and C show age distribution among prefectures/states in Japan and the USA, respectively. The vertical axis shows the percentage of age groups ≤14 years, 15–34 years, 35–64 years, and ≥65 years, and the horizontal axis shows the population sizes of the prefectures or states. For Japan, the approximation line was flat for the age group ≤14 years, rightward ascending in the age groups 15–34 years and 35–64 years, and rightward descending in the age group ≥65 years; indicating i) an accumulation of young people in the populated prefectures; ii) an increasing aged population in the less populated prefectures in Japan.

For the USA, however, the approximation lines were all horizontal; the age distribution was indifferent to the population size of the states, which may indicate that the age distribution was not the major determinant of the population size/density dependency of the HIV/AIDS epidemic in general.

In Japan, however, the concentration of the young generation in populated prefectures could have been contributed to i) the slightly larger m for “AIDS” in Japan (1.53) than in the USA (1.34) (compare panels B and D of Fig. 2); ii) the slightly larger m for “HIV” (1.63) than for “AIDS” (1.53) in Japan (compare panels A and B of Fig. 2); iii) the larger n for “HIV”
Fig. 11. Age distribution of homosexual and heterosexual HIV/AIDS patients in Japan (panel A), age distribution of population among different prefectures in Japan (panel B), and states (distinct) in the USA (panel C) according to the population size.

Panels A-1 and A-2: age distribution of heterosexual individuals (●) and homosexual individuals (○) for “HIV” (A-1) and for “AIDS” (A-2). Vertical axis: % occupied by each age group; horizontal axis: age groups: 1, ≤14; 2, 15–19; 3, 20–24; 4, 25–29; 5, 30–34; 6, 35–39; 7, 40–44; 8, 45–49; 9, 50–54; 10, 55–59; 11, 60–64; 12, ≥65. Panels B and C: age distribution according to the population size of prefectures in Japan (panel B) and states in the USA (panel C). Vertical axis: fraction of the age group among the total for each prefecture or state; horizontal axis: population size of prefecture or state. Data source for Japan is http://www.stat.go.jp/data/nihon/02.htm. Data source for the USA is Table 16 State Resident Population by Age and Sex: 2010, American National Standards Institute, Source: U.S. Census Bureau, “Demographic Profiles, Census 2010, available at September, 2011. Approximation lines were obtained by the logarithmic approximation calculated in the Excel file.

A stable relation was found between number of HIV/AIDS patients (P) and population size (N) and between incidence of HIV/AIDS (I) and population density (D), which could be expressed as $P = kN^m$ or $I = hD^n$, where $k$, $h$, $m$, and $n$ are constants; $m > 1$ indicated dependency of HIV/AIDS epidemic on population size, and $n > 0$ indicated dependency on population density. The constant $m$ was ~1.5 for “AIDS” in Japan and ~1.3 for “HIV/AIDS” in the USA; $n$ was 0.58 for “HIV” in Japan and 0.38 equally for “AIDS” in Japan and “AIDS diagnosis” in the USA.

It was surprising that the same equations were applicable to Japan and to the USA having the considerable demographic difference between the two countries (compare Fig. 11B and C). An important question is why high population size/density disproportionately increases number or incidence of HIV/AIDS cases.

Obviously, the major determinants are the size and density of population themselves, as the equations suggest. Increase of population size will increase number of encounters in proportion to the square of population size, and increase of population density will increase the chance of each possible encounter (5). However, increase of population size/density will accompany other changes that may directly affect the epidemic, such as transmission routes and epidemic webs (9).

Three lines of evidence put together suggested that, in populated prefectures in comparison with less populated prefectures, HIV was transmitted more frequently through the homosexual route than through the heterosexual route (at least in Japan). The evidences are: i) detection as “HIV” relative to “AIDS” was much more frequent among homosexual than among heterosexual individuals (8); ii) detection as “HIV” relative to “AIDS” was much more frequent in more populated prefectures than in less populated prefectures (Fig. 10A and B); and iii) the ratio of number of patients detected as “HIV” to number of patients detected as ”AIDS” was correlated with the ratio of homosexual infection to heterosexual infection with CC 0.77 (Table 1). Observa-
tions that homosexual men are generally young (Fig. 11A), and young people are concentrated in populated prefectures (Fig. 11B) further support this hypothesis. Namely, predominant homosexual transmission among the young population may have enhanced HIV transmission in populated prefectures in Japan.

There are, however, strong counterarguments against this hypothesis. In rural prefectures, detection of HIV infection is delayed until development of AIDS, because visiting clinicians for diagnosis is hampered by the eyes to the patient’s relatives or neighbors, and access to HIV-diagnosing clinics is limited there. This claim, however, is not supported by quantitative data. In addition, if the social barriers are so important in determining detection rate as “HIV” or “AIDS”, the “HIV” vs. “AIDS” plots could have been largely different between Japanese and non-Japanese populations in Japan, but the plot pattern was almost identical (compare Fig. 10A and B). In addition, the different detection pattern between homosexual and heterosexual individuals could be brought about by biological reasons (10).

The slope steeper than 1 of the log-log plot of patient number vs. population size, i.e., \( m > 1 \), could be explained by the chance that increases as the population increases as discussed above. In that case, however, \( m \) could have been 2, as in the case of rubella and measles (4), rather than 1.3\(^{2}~1.5 \) (Fig. 2). Therefore, though the simple chance factor may play a role, the prevalent homosexual transmission in the populated prefectures plays a significant role in the population dependency of the HIV/AIDS epidemic.

Human community is a product of complex interacting factors. Complex interacting events often create unique patterns, such as land and aquatic ecosystems, the structure of large cities, age structures, the global economy, embryo development, and group evolution of various living organisms (11). The observed simple mathematical equation for the HIV/AIDS epidemic may be one such example.

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**REFERENCES**