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This supplementary material has been provided by the authors to give readers additional information about their work.
eAppendix 1. Concept of Population-Attributable Fraction (AFp) and Population Impact Fraction (IFp): What They Mean and Calculation

1) AFp

The intervention is associated with better survival probability.

P: proportion of those who received the intervention
Iu: proportion of survival among those who do not receive the intervention
Ia: proportion of survival among those who received the intervention

AFp indicates theoretical proportional change of the targeted outcome (survival in this example) by comparing counterfactual situations where there was no exposure to a risk factor (an intervention in this example), assuming the other factors were constant.1 This assumption may be unrealistic in some cases. In situations without the intervention, another intervention might have been performed or other factors might have changed.

AFp is the proportion of the increment associated with the intervention (D) in the current total survival (how much percentage of the survival would reduce without the
intervention?).

\[ AF_p = \frac{D}{A}, \]

where

\[ A: \text{current total survival} = I_a \times P + I_u \times (1 - P) \]

\[ D: \text{survival increment associated with the intervention} = (I_a - I_u) \times P \]

**Calculation example**

If the survival probability of those who received the intervention is 25%, that of those who do not is 15%, and 50% of the population receive the intervention:

\[ I_u = 0.15 \]
\[ I_a = 0.25 \]
\[ P = 0.5 \]

\[ AF_p = \frac{(0.25 - 0.15) \times 0.5}{0.25 \times 0.5 + 0.15 \times 0.5} = 0.25 \]

Without the intervention, the survival would reduce by 25%.

**Formula modification**

The proportion of those who receive the intervention among those who survive \( (P') \) is calculate as:

\[ P' = \frac{I_a \times P}{A}, \]

\[ \frac{P'}{I_a} = \frac{P}{A} \]

Thus

\[ AF_p = \frac{D}{A} = \frac{(I_a - I_u) \times P}{A} = \frac{(I_a - I_u) \times P'}{I_a} = \frac{(I_a/I_u - 1) \times P'}{I_a/I_u} \]
Here, relative risk for the intervention is:

\[ r = \frac{I_a}{I_u} \]

Thus,

\[ AF_p = \frac{(r - 1)}{r} \times P' \]

2) IFp

The intervention is associated with better survival and intervention increased from time 1 to time 2.

P₁: proportion of those who received the intervention at time 1

P₂: proportion of those who received the intervention at time 2

I_u: proportion of survival among those who do not receive the intervention

I_a: proportion of survival among those who received the intervention

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Whereas AFp is a comparison with a counterfactual situation, IFp is a more realistic comparison: comparison between the current situation and the past situation (what actually happened several years ago).²

IFp is a proportion of partial survival increment (d) associated with increased intervention from time 1 to time 2 in the total survival (how much percentage would reduce when the situation went back to time 1?).

\[
IF_p = \frac{d}{A},
\]

where

A: total survival at time 2 = \( I_a \times P_2 + I_u \times (1 - P_2) \)

d: a partial survival increment associated with increased intervention from time 1 to time 2 = \( (I_a - I_u) \times (P_2 - P_1) \)

Calculation example

If the survival probability of those who received the intervention is 50%, that of those who do not is 40%, and 10% of the population receive the intervention at time 1 and 20% at time 2.

\[
IF_p = \frac{(0.5 - 0.4) \times (0.2 - 0.1)}{0.5 \times 0.2 + 0.4 \times 0.8} = 0.0238 \ldots
\]

If the exposure to the intervention went back to the level at time 1, the survival would reduce by 2.4%. In other words, 2.4% of the current (time 2) survival was associated with the increase of the intervention from time 1 to time 2.

Modification of the formula

\[
IF_p = \frac{d}{A} = \frac{(I_a - I_u) \times (P_2 - P_1)}{I_a \times P_2 + I_u \times (1 - P_2)} = \frac{(I_a/I_u - 1) \times (P_2 - P_1)}{I_a/I_u \times P_2 + 1 - P_2} = \frac{(r - 1) \times (P_2 - P_1)}{r \times P_2 + 1 - P_2}
\]

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Here, relative risk for the intervention is:

\[ r = \frac{I_a}{I_u} \]
eAppendix 2. Calculation of Population-Attributable Fraction (AF_p) for Defibrillation and Chest Compression

1) Defibrillation

\[ P_{\text{byst}} \]: proportion of those who received bystander defibrillation among the bystander-witnessed presumed cardiac origin out-of-hospital cardiac arrest (OHCA) patients

\[ P_{\text{ems}} \]: proportion of those who received emergency medical service (EMS) defibrillation

\[ P_{\text{com}} \]: proportion of those who received combined defibrillation by bystander and EMS

\[ P_{\text{u}} \]: proportion of those who received no defibrillation

\[ I_{\text{byst}}, I_{\text{com}}, I_{\text{ems}}, \text{and} I_{\text{u}} \] indicate proportions of neurologically intact survival among those who received respective interventions.

The population attributable fraction for all defibrillation combined (AF_p-def) is calculated relative to the situation where there is no defibrillation as:

\[ \text{AF}_{p-\text{def}} = \frac{D}{A} , \]

where

\[ A = I_{\text{byst}} \times P_{\text{byst}} + I_{\text{com}} \times P_{\text{com}} + I_{\text{ems}} \times P_{\text{ems}} + I_{\text{u}} \times P_{\text{u}} \]

\[ D = (I_{\text{byst}} - I_{\text{u}}) \times P_{\text{byst}} + (I_{\text{com}} - I_{\text{u}}) \times P_{\text{com}} + (I_{\text{ems}} - I_{\text{u}}) \times P_{\text{ems}} \]

D is the increment of neurologically intact survival by all defibrillation

Thus,

\[ \text{AF}_{p-\text{def}} = \frac{D}{A} = \frac{(I_{\text{byst}} - I_{\text{u}}) \times P_{\text{byst}}}{A} + \frac{(I_{\text{com}} - I_{\text{u}}) \times P_{\text{com}}}{A} + \frac{(I_{\text{ems}} - I_{\text{u}}) \times P_{\text{ems}}}{A} \]

The proportions of those who received the above-mentioned interventions among those who obtained neurologically intact survival (P'_{\text{byst}}, P'_{\text{com}}, P'_{\text{ems}}, P'_{\text{u}}) are calculated as:

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\[ P_{\text{byst}}' = \frac{l_{\text{byst}} \times P_{\text{byst}}}{A}, P_{\text{com}}' = \frac{l_{\text{com}} \times P_{\text{com}}}{A}, P_{\text{ems}}' = \frac{l_{\text{ems}} \times P_{\text{ems}}}{A}, \]

\[ \frac{P_{\text{byst}}}{A} = \frac{P_{\text{byst}}'}{l_{\text{byst}}}, \frac{P_{\text{com}}}{A} = \frac{P_{\text{com}}'}{l_{\text{com}}}, \frac{P_{\text{ems}}}{A} = \frac{P_{\text{ems}}'}{l_{\text{ems}}} \]

Thus the formula of \( \text{AF}_{p-def} \) is:

\[
\text{AF}_{p-def} = \frac{(l_{\text{byst}}/l_u - 1) \times P_{\text{byst}}'}{l_{\text{byst}}/l_u} + \frac{(l_{\text{com}}/l_u - 1) \times P_{\text{com}}'}{l_{\text{com}}/l_u} + \frac{(l_{\text{ems}}/l_u - 1) \times P_{\text{ems}}'}{l_{\text{ems}}/l_u}
\]

Here, relative risks for the defibrillation by bystander alone, combined defibrillation, and defibrillation by EMS alone compared with no defibrillation are \( r_{\text{byst}}, r_{\text{com}}, \) and \( r_{\text{ems}}, \) respectively:

\[
r_{\text{byst}} = \frac{l_{\text{byst}}}{l_u}, r_{\text{com}} = \frac{l_{\text{com}}}{l_u}, r_{\text{ems}} = \frac{l_{\text{ems}}}{l_u}
\]

Thus

\[
\text{AF}_{p-def} = \frac{(r_{\text{byst}} - 1)}{r_{\text{byst}}} \times P_{\text{byst}}' + \frac{(r_{\text{com}} - 1)}{r_{\text{com}}} \times P_{\text{com}}' + \frac{(r_{\text{ems}} - 1)}{r_{\text{ems}}} \times P_{\text{ems}}'
\]

Population attributable fraction for each of the defibrillations is:

\[
\text{AF}_{p-\text{byst}} = \frac{(r_{\text{byst}} - 1)}{r_{\text{byst}}} \times P_{\text{byst}}' = \frac{D_{\text{byst}}}{A},
\]

\[
\text{AF}_{p-\text{com}} = \frac{(r_{\text{com}} - 1)}{r_{\text{com}}} \times P_{\text{com}}' = \frac{D_{\text{com}}}{A},
\]

\[
\text{AF}_{p-\text{ems}} = \frac{(r_{\text{ems}} - 1)}{r_{\text{ems}}} \times P_{\text{ems}}' = \frac{D_{\text{ems}}}{A}
\]

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P: proportion of those who received bystander chest compression among the bystander-witnessed presumed cardiac origin out-of-hospital cardiac arrest (OHCA) patients

\( I_{cc} \) and \( I_u \) indicate proportions of neurologically intact survival among those who received chest compression and those who did not

The population attributable fraction (AF<sub>p−cc</sub>) is:

\[
AF_{p-cc} = \frac{D}{A}
\]

Where

\[
A = I_{cc} \times P + I_u \times (1 - P)
\]

\[
D = (I_{cc} - I_u) \times P
\]

Thus,

\[
AF_{p-cc} = \frac{D}{A} = \frac{(I_{cc} - I_u) \times P}{A} = \frac{(I_{cc} - I_u) \times P'}{I_{cc}} = \frac{(r_{cc} - 1) \times P'}{r_{cc}},
\]

where

\[
p' = \frac{P_2}{I_{cc}} \quad A = \frac{I_{cc}}{I_u} \quad r_{cc} = \frac{I_{cc}}{I_u}
\]
**eAppendix 3. Calculation of Population Impact Fraction (IFp) for Defibrillation and Chest Compression**

1) **Defibrillation**

The partial increment by bystander defibrillation is the shaded part ($D'$): without bystander defibrillation, EMS would have provided defibrillation. The population impact fraction by bystander defibrillation (bystander alone or combined with EMS defibrillation ($IF_{p-byst/com}$)) is:

$$IF_{p-byst/com} = \frac{D'}{A}$$

Where

$$A = byst × P_{byst} + com × P_{com} + ems × P_{ems} + u × P_u$$

$$D' = \left(byst - ems\right) × P_{byst} + \left(com - ems\right) × P_{com}$$

$D'$ is the increment of survival due to increased exposure to an intervention (a partial increment)

Thus,

$$IF_{p-byst/com} = \frac{D'}{A} = \frac{\left(byst - ems\right) × P_{byst}}{A} + \frac{\left(com - ems\right) × P_{com}}{A}$$

$$= \frac{\left(byst - ems\right)}{byst} × P_{byst}' + \frac{\left(com - ems\right)}{com} × P_{com}'$$

$$= \frac{\left(byst / ems - 1\right) × P_{byst}'}{byst / ems} + \frac{\left(com / ems - 1\right) × P_{com}'}{com / ems}$$

Here,

$$r_{byst}' = \frac{byst}{ems}, r_{com}' = \frac{com}{ems}$$

Thus

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The partial increment \( (D') \) is estimated by multiplying the IF\(_p\) with the number of neurologically intact survival (A).

2) Chest compression

\[
IF_{p-byst/com} = \frac{r'_byst - 1}{r'_byst} \times P'_byst + \frac{r'_com - 1}{r'_com} \times P'_com
\]

\( P_1 \): proportion of those who received bystander chest compression among the bystander-witnessed presumed cardiac origin OHCA patients at time 1

\( P_2 \): proportion of those who received bystander chest compression among the bystander-witnessed presumed cardiac origin OHCA patients at time 2

\( I_{cc} \) and \( I_u \) indicate proportions of neurologically intact survival among those who received chest compression and those who did not

The partial increment by chest compression is \( d \).

The population impact fraction\(^2\) of chest compression at time 2 relative to time 1 \( (IF_{p-cc}) \):

\[
IF_{p-cc} = \frac{d}{A}
\]

where

\[
A = (I_{cc} - I_u) \times P_2 + I_u
\]

\[
d = (I_{cc} - I_u) \times (P_2 - P_1)
\]

Thus,

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\[
IF_{p-cc} = \frac{d}{A} = \frac{(I_{cc} - I_u) \times (P_2 - P_1)}{A} = \frac{(I_{cc} - I_u) \times (P_2 - P_1)}{(I_{cc} - I_u) \times P_2 + I_u} = \frac{(r_{cc} - 1) \times (P_2 - P_1)}{(r_{cc} - 1) \times P_2 + 1}
\]
eAppendix 4. Survival Increment Attributable to Increased Interventions by Bystanders

A partial increment, the survival increment attributable to increased exposure to an intervention, was estimated by multiplying the $IF_p$ with the number of neurologically intact survivors. Proportions of the partial increments in the total increments (excess survival) show the proportional association of the increased procedures to the survival increments. The $IF_p$s for bystander defibrillation were based on the comparison with the situation before June 2004 as mentioned above, whereas the total increments were based on the comparison with the situation in 2005. Because bystander defibrillation in 2005 was negligible, we approximated the situation before 2004 (data were unavailable) by that in 2005. A calculation example is shown below.

We calculated 95% CIs for the AFps following the method described by Greenland.1 For IFps and partial increments, we calculated the best estimates based on the odds ratios estimated in the logistic model, and the minimum and maximum values based on the lower and upper limits of the 95% CIs of the odds ratios.

A calculation example

In 2012, the $IF_p$ for defibrillation by bystander alone was calculated as:

$$\frac{2.24 - 1}{2.24} \times 0.127 = 0.0703,$$

where the OR for bystander defibrillation compared with EMS defibrillation was 2.24; the proportion of those who received defibrillation by bystander among those who attained neurologically intact survival was 0.127.

$IF_p$ for combined defibrillation by both bystander and EMS was calculated as:

$$\frac{1.50 - 1}{1.50} \times 0.058 = 0.0193,$$

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where the OR for combined defibrillation compared with EMS defibrillation was 1.50; the proportion of those who received combined defibrillation among those who attained neurologically intact survival was 0.058.

Thus, IF<sub>p</sub> for bystander defibrillation as a whole (with or without EMS defibrillation) was

\[ 0.0703 + 0.0193 = 0.0896 \]

Estimated increment of survival was calculated as:

\[ 1710 \times 0.0896 = 153, \]

where the number of neurologically intact survival in 2012 was 1710.

The proportion of the estimated increments due to increased bystander defibrillation use in 2012 was calculated as:

\[ \frac{153}{1030} = 0.149, \]

where total increment of survival (difference between actual number of survival and expected number) was 1030.
**eResults**

**eTable 1.** Associations Between Bystander Type (Family or Nonfamily) and Bystander Interventions

(n=167,912)

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**Table 2.** Full Model of Multivariate Logistic Regression Analysis with Neurologically Intact Survival as the Outcome (n=167,312)*

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<td>0.07</td>
<td>0.06</td>
<td>0.08</td>
</tr>
<tr>
<td>Other</td>
<td>3.53</td>
<td>3.15</td>
<td>3.95</td>
</tr>
<tr>
<td><strong>Bystander chest compression</strong></td>
<td>1.52</td>
<td>1.45</td>
<td>1.60</td>
</tr>
<tr>
<td><strong>Defibrillation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bystander alone</td>
<td>5.15</td>
<td>4.50</td>
<td>5.90</td>
</tr>
<tr>
<td>Combined</td>
<td>3.44</td>
<td>2.94</td>
<td>4.03</td>
</tr>
<tr>
<td>EMS alone</td>
<td>2.30</td>
<td>2.08</td>
<td>2.55</td>
</tr>
</tbody>
</table>

Prefectures were not shown in the table.

VF/VT ventricular fibrillation or pulseless ventricular tachycardia, PEA pulseless electrical activity, CI confidence interval.

*: We excluded those with impossible (≦0 min.) or outlying (>120 min.) time data in the call to contact interval or contact to hospital arrival interval (n=600)
eFigure. Calibration Graph of Predicted and Observed Survival

Calibration graph comparing predicted and observed survival

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**eTable 3.** Estimation of Population-Attributable Fraction (AF<sub>p</sub>), Population Impact Fraction (IF<sub>p</sub>), and Survival Increments

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
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<tr>
<td><strong>Population attributable fraction AF&lt;sub&gt;p&lt;/sub&gt; (95% CI)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Defibrillation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bystander only</td>
<td>0.8</td>
<td>3.6</td>
<td>4.7</td>
<td>7.3</td>
<td>7.7</td>
<td>8.8</td>
<td>8.9</td>
<td>10.2</td>
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<tr>
<td></td>
<td>(0.0–1.6)</td>
<td>(2.1–5.0)</td>
<td>(3.3–6.0)</td>
<td>(5.7–8.8)</td>
<td>(6.2–9.2)</td>
<td>(7.2–10.4)</td>
<td>(7.4–10.5)</td>
<td>(8.6–11.8)</td>
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<tr>
<td>Combined (Bystander + EMS)</td>
<td>0.6</td>
<td>0.7</td>
<td>2.0</td>
<td>2.6</td>
<td>3.1</td>
<td>4.0</td>
<td>4.3</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>(0.0–1.3)</td>
<td>(0.0–1.4)</td>
<td>(1.1–2.9)</td>
<td>(1.6–3.6)</td>
<td>(2.1–4.2)</td>
<td>(2.8–5.1)</td>
<td>(3.1–5.4)</td>
<td>(3.0–5.3)</td>
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<tr>
<td><strong>EMS only</strong></td>
<td>41.5</td>
<td>41.2</td>
<td>38.4</td>
<td>36.9</td>
<td>36.8</td>
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<td>(35.3–46.6)</td>
<td>(33.5–42.9)</td>
<td>(32.2–41.2)</td>
<td>(32.4–41.0)</td>
<td>(31.0–39.3)</td>
<td>(28.2–35.9)</td>
<td>(27.8–35.4)</td>
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<tr>
<td>Bystander chest compression</td>
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<td>19.5</td>
<td>20.7</td>
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<td>22.3</td>
<td>23.3</td>
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<td>(13.7–22.8)</td>
<td>(15.2–23.6)</td>
<td>(16.9–24.3)</td>
<td>(18.3–25.7)</td>
<td>(18.6–25.8)</td>
<td>(19.6–26.8)</td>
<td>(19.4–26.4)</td>
<td>(20.0–27.1)</td>
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<td><strong>Population impact fraction IF&lt;sub&gt;p&lt;/sub&gt; and partial increments (range)</strong></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bystander defibrillation (Bystander only + Combined)*</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IF&lt;sub&gt;p&lt;/sub&gt; %</td>
<td>–</td>
<td>2.8</td>
<td>4.1</td>
<td>6.2</td>
<td>6.8</td>
<td>7.9</td>
<td>8.1</td>
<td>9.0</td>
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<td></td>
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<td>(3.4–4.7)</td>
<td>(5.2–7.1)</td>
<td>(5.6–7.7)</td>
<td>(6.6–9.1)</td>
<td>(6.7–9.4)</td>
<td>(7.5–10.3)</td>
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</tr>
<tr>
<td>No.‡</td>
<td>–</td>
<td>21</td>
<td>49</td>
<td>80</td>
<td>101</td>
<td>122</td>
<td>137</td>
<td>153</td>
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<tr>
<td>%§</td>
<td>–</td>
<td>13.3</td>
<td>8.6</td>
<td>12.3</td>
<td>11.8</td>
<td>13.9</td>
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<td>(11.5–15.9)</td>
<td>(11.4–15.8)</td>
<td>(12.4–17.0)</td>
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<tr>
<td>Bystander chest compression</td>
<td>IF&lt;sub&gt;p&lt;/sub&gt; %</td>
<td>–</td>
<td>1.2</td>
<td>3.3</td>
<td>3.6</td>
<td>5.0</td>
<td>4.4</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>(1.0–1.3)</td>
<td>(2.9–3.6)</td>
<td>(3.1–4.0)</td>
<td>(4.4–5.6)</td>
<td>(3.9–4.9)</td>
<td>(3.8–4.8)</td>
<td>(4.5–5.7)</td>
<td></td>
</tr>
<tr>
<td>No.‡</td>
<td>–</td>
<td>9</td>
<td>39</td>
<td>46</td>
<td>75</td>
<td>67</td>
<td>72</td>
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<tr>
<td>%§</td>
<td>–</td>
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<td>6.9</td>
<td>7.1</td>
<td>8.7</td>
<td>7.6</td>
<td>7.3</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>(4.9–6.3)</td>
<td>(6.1–7.7)</td>
<td>(6.2–7.9)</td>
<td>(7.7–9.7)</td>
<td>(6.8–8.5)</td>
<td>(6.4–8.1)</td>
<td>(7.4–9.4)</td>
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<tr>
<td>Total increments†</td>
<td>No.</td>
<td>–</td>
<td>161</td>
<td>569</td>
<td>652</td>
<td>854</td>
<td>881</td>
<td>990</td>
</tr>
</tbody>
</table>

AF<sub>p</sub>: population attributable fraction, IF<sub>p</sub>: population impact fraction, EMS: emergency medical services.

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*: This category indicates sum of the IFₚ of bystander only defibrillation and that of combined defibrillation

†: Total increments are differences between the actual numbers of survival and the expected numbers based on the survival rate in 2005.

‡: The numbers of partial increments are calculated by multiplying the IFₚs to the actual numbers of survival.

§: The proportions of partial increments in the total increments.
References
