Housing & malaria – new opportunities for control and elimination

Prof Steve Lindsay
What I’m going to cover

• Making the case for housing as a malaria control intervention
• Estimating the effect size of ‘good’ quality housing
• Doing the experiment to measure the protective efficacy of housing against clinical malaria
Principal Pillars of Public Health

Clean water
Sanitation
Housing
80% malaria transmission in sub-Saharan Africa occurs indoors

Future opportunities

• Quiet revolution: housing in Africa is changing from thatch to metal roofed houses
• 115 M rural houses to be built in Africa by 2050
• Insecticide-resistance strategy
• Help move to elimination
House improvements in Korogwe, Tanzania, 1975–2008

New RBM/UNDP calls for action outside the health sector to control malaria – including housing.
Integrated Vector Management

• IVM is a World Health Organisation recommended management approach for the control of VBDs globally.

• Advocates interventions both within and outside the health sector
The evidence for improving housing to reduce malaria: a systematic review & meta-analysis

Tusting LS, Ippolito M, Willey B, Kleinschmidt I, Dorsey G, Gosling R, Lindsay SW
Rationale

• Despite historical precedent for housing in malaria control, few rigorously conducted studies – only one intervention study with epidemiological outcomes (Kirby 2009 Lancet)

• *Multisectoral Action Framework for Malaria* emphasises need for good housing - yet a paucity of supporting evidence

• We undertook the first systematic review and meta-analysis of housing and malaria, to:
  1. Characterise all published and unpublished data
  2. Assess strength and quality of the evidence
Methods

• **Aim:** To assess whether modern housing is associated with a lower risk of malaria than traditional housing, across all age groups and malaria-endemic settings

• **Search strategy:** six electronic databases and grey literature; intervention and observational studies published from 1\(^{st}\) Jan 1900 to 13\(^{th}\) Dec 2013

• **Analysis:** Crude and adjusted effects combined in meta-analyses, with subgroup analyses for:
  • Overall house type (traditional versus modern housing)
  • Main roof, wall and floor materials
  • Eave type
  • House screening
Results

• 15526 studies screened → 90 included in a qualitative synthesis and 52 included in meta-analysis

• Compared to traditional homes, residents of modern homes had:
  • 42% lower odds of malaria infection
    • Adjusted OR 0.58, 95% CI 0.44–0.75, p<0.001
  • 54–65% lower odds of clinical malaria
    • Case-control studies: adj OR 0.35, 95%CI 0.20–0.62, p<0.001
    • Cohort studies: adj RR 0.46, 95%CI 0.33–0.65, p<0.001
Association between modern housing and malaria infection

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log[Odds Ratio]</th>
<th>SE</th>
<th>Weight</th>
<th>Odds Ratio IV, Random, 95% CI</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1.1 Case-control, cross-sectional and cohort studies (crude odds ratio)</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Al-Makhlafi 2011 YEM (1)</td>
<td>-0.328504</td>
<td>0.382809</td>
<td>9.5%</td>
<td>0.72 [0.34, 1.52]</td>
<td></td>
</tr>
<tr>
<td>Barber 1935 GRC (2)</td>
<td>-0.554898</td>
<td>0.320402</td>
<td>11.4%</td>
<td>0.57 [0.31, 1.08]</td>
<td></td>
</tr>
<tr>
<td>Butraporn 1935 THA (3)</td>
<td>-1.347074</td>
<td>0.133859</td>
<td>18.4%</td>
<td>0.26 [0.20, 0.34]</td>
<td></td>
</tr>
<tr>
<td>Daresh 2009 EGY (4)</td>
<td>-0.392042</td>
<td>0.459362</td>
<td>7.7%</td>
<td>0.68 [0.27, 1.66]</td>
<td></td>
</tr>
<tr>
<td>de Alemida 2010 TLS (5)</td>
<td>-1.407117</td>
<td>1.458633</td>
<td>11.1%</td>
<td>0.24 [0.01, 4.27]</td>
<td></td>
</tr>
<tr>
<td>Osterbauer 2012 UGA (6)</td>
<td>-1.514128</td>
<td>0.525624</td>
<td>6.4%</td>
<td>0.22 [0.08, 0.62]</td>
<td></td>
</tr>
<tr>
<td>van der Hoek 2003 LKA (7)</td>
<td>-0.875469</td>
<td>0.195404</td>
<td>16.0%</td>
<td>0.42 [0.28, 0.61]</td>
<td></td>
</tr>
<tr>
<td>Wolff 2001 MWI (8)</td>
<td>-0.371064</td>
<td>0.331932</td>
<td>11.0%</td>
<td>0.69 [0.36, 1.32]</td>
<td></td>
</tr>
<tr>
<td>Woyessa 2013 ETH (9)</td>
<td>-0.634878</td>
<td>0.13098</td>
<td>18.5%</td>
<td>0.53 [0.41, 0.69]</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td></td>
<td></td>
<td>100.0%</td>
<td>0.46 [0.33, 0.62]</td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: $$\tau^2 = 0.12; \chi^2 = 23.85, \text{df} = 8 (P = 0.002); I^2 = 66\%$$
Test for overall effect: $$Z = 4.92 (P < 0.00001)$$

| **1.1.2 Case-control, cross-sectional and cohort studies (adjusted odds ratio)** |
|-------------------------------------------|-----------------|-------|--------|--------------------------------|--------------------------------|
| de Beaudrap 2001 UGA (10)                | -0.494296       | 0.202705 | 42.0%  | 0.61 [0.41, 0.91]             |                                |
| Osterbauer 2012 UGA (11)                 | -1.386294       | 0.521251 | 6.6%   | 0.25 [0.09, 0.69]             |                                |
| van der Hoek 2003 LKA (12)               | -0.553885       | 0.21463 | 37.7%  | 0.57 [0.38, 0.88]             |                                |
| Wolff 2001 MWI (13)                      | -0.314711       | 0.360684 | 13.7%  | 0.73 [0.36, 1.48]             |                                |
| **Subtotal (95% CI)**                    |                 |        | 100.0% | 0.58 [0.44, 0.75]             |                                |

Heterogeneity: $$\tau^2 = 0.00; \chi^2 = 3.08, \text{df} = 3 (P = 0.38); I^2 = 2\%$$
Test for overall effect: $$Z = 4.10 (P < 0.00001)$$

Test for subgroup differences: $$\chi^2 = 1.24, \text{df} = 1 (P = 0.27); I^2 = 19.5\%$$
Association between modern housing and clinical malaria

### 1.2.1 Case-control and cross-sectional studies (crude odds ratio)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log(Odds Ratio)</th>
<th>SE</th>
<th>Weight</th>
<th>Odds Ratio IV, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danis-Lozano 2007 MEX (1)</td>
<td>-1.141033</td>
<td>0.263875</td>
<td>100.0%</td>
<td>0.32 [0.19, 0.54]</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td></td>
<td></td>
<td>100.0%</td>
<td>0.32 [0.19, 0.54]</td>
</tr>
</tbody>
</table>

Heterogeneity: Not applicable
Test for overall effect: $Z = 4.32$ (P < 0.0001)

### 1.2.2 Case-control and cross-sectional studies (adjusted odds ratio)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log(Odds Ratio)</th>
<th>SE</th>
<th>Weight</th>
<th>Odds Ratio IV, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danis-Lozano 2007 MEX (2)</td>
<td>-1.047319</td>
<td>0.287815</td>
<td>100.0%</td>
<td>0.35 [0.20, 0.62]</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td></td>
<td></td>
<td>100.0%</td>
<td>0.35 [0.20, 0.62]</td>
</tr>
</tbody>
</table>

Heterogeneity: Not applicable
Test for overall effect: $Z = 3.64$ (P = 0.0003)

### 1.2.3 Cohort studies (crude rate ratio)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log(Odds Ratio)</th>
<th>SE</th>
<th>Weight</th>
<th>Odds Ratio IV, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liu 2014 TZA (3)</td>
<td>-1.789761</td>
<td>0.388411</td>
<td>26.1%</td>
<td>0.17 [0.08, 0.36]</td>
</tr>
<tr>
<td>Peterson 2009a ETH (4)</td>
<td>-0.765468</td>
<td>0.521061</td>
<td>16.0%</td>
<td>0.47 [0.17, 1.29]</td>
</tr>
<tr>
<td>Peterson 2009b ETH (5)</td>
<td>-1.568616</td>
<td>0.213907</td>
<td>57.9%</td>
<td>0.21 [0.14, 0.32]</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td></td>
<td></td>
<td>100.0%</td>
<td>0.22 [0.14, 0.35]</td>
</tr>
</tbody>
</table>

Heterogeneity: $\tau^2 = 0.04$; $\chi^2 = 2.63$, df = 2 (P = 0.27); $I^2 = 24$
Test for overall effect: $Z = 6.70$ (P < 0.00001)

### 1.2.4 Cohort studies (adjusted rate ratio)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log(Odds Ratio)</th>
<th>SE</th>
<th>Weight</th>
<th>Odds Ratio IV, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liu 2014 TZA (6)</td>
<td>-1.127012</td>
<td>0.399761</td>
<td>18.4%</td>
<td>0.32 [0.15, 0.71]</td>
</tr>
<tr>
<td>Peterson 2009b ETH (7)</td>
<td>-0.693147</td>
<td>0.189573</td>
<td>81.6%</td>
<td>0.50 [0.34, 0.72]</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td></td>
<td></td>
<td>100.0%</td>
<td>0.46 [0.33, 0.65]</td>
</tr>
</tbody>
</table>

Heterogeneity: $\tau^2 = 0.00$; $\chi^2 = 0.96$, df = 1 (P = 0.33); $I^2 = 0$
Test for overall effect: $Z = 4.51$ (P < 0.00001)

Test for subgroup differences: $\chi^2 = 6.74$, df = 3 (P = 0.08); $I^2 = 55.5\%$
Conclusion

• ‘Good’ quality housing associated with substantial reduction in clinical malaria and infection;
• We found a high risk of bias within and across studies
• Cannot be entirely confident that there is no residual confounding associated with socio-economic status
• Increase in modern house may contribute to some of the decline in malaria over the past 12 years
• Need to do randomised-controlled trials
Randomised-controlled study in The Gambia

Control (no screening)       Screened ceilings       Fully Screened
N=100                         N=200                          N=200
Screening interventions

Ceiling screens

Closed eaves, screened doors & windows
## Trial Outcomes

<table>
<thead>
<tr>
<th></th>
<th>No screening (n=96)</th>
<th>Screened ceiling (n=178)</th>
<th>% reduction</th>
<th>Full screening (n=188)</th>
<th>% reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>An. gambiae s.l.</em></td>
<td>12.4 (9.9-15.3)</td>
<td>6.0 (5.1-7.0)</td>
<td>↓52*</td>
<td>4.6 (3.9-5.4)</td>
<td>↓63*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>OR (95% CI)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaemia (&lt;8g/dL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Screened ceiling</td>
<td>0.48 (0.26-0.91)</td>
<td>0.02</td>
</tr>
<tr>
<td>Full screening</td>
<td>0.51 (0.28-0.95)</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Kirby et al., 2009 *Lancet*
Can improved housing provide additional protection against clinical malaria over current best practice? A household-randomised controlled study.

Lindsay SW, Conteh, L, D’Alessandro, U, Kandeh, B, Knudsen, U, Jones, C, Pinder, M, Sicuri, E.

Financed by MRC-DfID-Wellcome Trust Global Health Trials
Study plan

• Randomised controlled trial
• Study on how to scale-up these interventions
Study interventions

Traditional

Control houses
1. mud walls
2. thatch roof
3. open eaves
4. At least one child
5. LLIN provided

Modern

Intervention houses
1. mud walls
2. metal roof
3. closed eaves
4. untreated screening
5. at least one child
2. LLIN provided
What the interventions look like:

Square-based houses

Circular-based houses
Study plan

• Comparison between traditional vs modern housing
• Both arms will have LLINs
• Maximum of 5 houses from each arm selected in each village (i.e. 5 traditional & 5 modern houses/village)
• 400 traditional houses vs 400 modern houses
• Followed for two years (2 transmission seasons)
• Main outcomes
  1. incidence of clinical malaria measured using active case detection
  2. number of *Anopheles gambiae* collected indoors using light traps
Additional questions to be addressed

• Are these interventions acceptable and durable?
• Are these interventions cost-effective?
• Can we develop a strategy for potential scale-up of housing interventions?
Summary

- Evidence that housing protects against malaria across the world
- Potentially important measure for malaria control, insecticide-resistance management strategy & for elimination
- Strategic intervention to be a supplementary method of control
- RCT in progress to measure the efficacy of ‘good’ housing against malaria
- More RCTs needed in other parts of sub-Saharan Africa
- New interventions & pathways to impact need to be developed