Affordable house designs to improve health in rural Africa: a field study from northeastern Tanzania

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Summary

Background The population of sub-Saharan Africa is currently estimated to be 1245 million and is expected to quadruple by the end of the century, necessitating the building of millions of homes. Malaria remains a substantial problem in this region and efforts to minimise transmission should be considered in future house planning. We studied how building elements, which have been successfully employed in southeast Asia to prevent mosquitoes from entering and cooling the house, could be integrated in a more sustainable house design in rural northeastern Tanzania, Africa, to decrease mosquito density and regulate indoor climate.

Methods In this field study, six prototype houses of southeast Asian design were built in the village of Magoda in Muheza District, Tanga Region, Tanzania, and compared with modified and unmodified, traditional, sub-Saharan African houses. Prototype houses were built with walls made of lightweight permeable materials (bamboo, shade net, or timber) with bedrooms elevated from the ground and with screened windows. Modified and unmodified traditional African houses, wattle-daub or mud-block constructions, built on the ground with poor ventilation served as controls. In the modified houses, major structural problems such as leaking roofs were repaired, windows screened, open eaves blocked with bricks and mortar, cement floors repaired or constructed, and rain gutters and a tank for water storage added. Prototype houses were randomly allocated to village households through a free, fair, and transparent lottery. The lottery tickets were deposited in a bucket made of transparent plastic. Each participant could draw one ticket. Hourly measurements of indoor temperature and humidity were recorded in all study houses with data loggers and mosquitoes were collected indoors and outdoors using Furvela tent traps and were identified with standard taxonomic keys. Mosquitoes of the Anopheles gambiae complex were identified to species using PCR. Attitudes towards the new house design were assessed 6–9 months after the residents moved into their new or modified homes through 15 in-depth interviews with household heads of the new houses and five focus group discussions including neighbours of each group of prototype housing.

Findings Between July, 2014, and July, 2015, six prototype houses were constructed; one single and one double storey building with each of the following claddings: bamboo, shade net, and timber. The overall reduction of all mosquitoes caught was highest in the double-storey buildings (96%; 95% CI 92–98) followed closely by the reduction found in single-storey buildings (77%; 72–82) and lowest in the modified reference houses (43%; 36–50) and unmodified reference houses (23%; 18–29). The indoor temperature in the new design houses was 2·3°C (95% CI 2·2–2·4) cooler than in the reference houses. While both single and two-storey buildings provided a cooler indoor climate than did traditional housing, two-storey buildings provided the biggest reduction in mosquito densities (96%, 95% CI 89–100). Seven people who moved into the prototype houses and seven of their neighbours (three of whom had their houses modified) participated in in-depth interviews. After living in their new prototype houses for 6–9 months, residents expressed satisfaction with the new design, especially the second-storey sleeping area because of the privacy and security of upstairs bedrooms.

Interpretation The new design houses had fewer mosquitoes and were cooler than modified and unmodified traditional homes. New house designs are an underused intervention and hold promise to reduce malaria transmission in sub-Saharan Africa and keep areas malaria-free after elimination.

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Research in context

Evidence before this study
We searched PubMed between Jan 1, 2010, and July 21, 2017, with the terms “housing”, combined with “Africa”, “health”, and/or “malaria” with no date restrictions for published English-language reports. We found two large reviews have assessed the evidence for housing improvements (other than bednets) to reduce malaria in sub-Saharan Africa. The first was a systematic review and meta-analysis of 90 studies published between 1900 and 2013. Residents of modern houses had 47% lower odds of malaria infection than did those of traditional houses and a 45–65% lower odds of clinical malaria. Traditional homes were deemed as those having mud walls, thatched roofs, earth floors, open eaves, no ceiling, and no screening. Improved homes had full or ceiling screening, finished walls and floors, corrugate iron roofs, and closed eaves. A more recent multi-country analysis of 15 demographic and health surveys and 14 Malaria Indicator Surveys done in 21 countries across sub-Saharan Africa confirmed that housing quality is an important risk factor for malaria infection across the spectrum of malaria endemicity. Importantly, this analysis noted that the protection afforded by improved housing quality against malaria was similar to the protection afforded by impregnated bednets.

Added value of this study
Our findings showed that a southeast Asian house design (with elevated structure, screened windows, and permeable walls to maximise cross-ventilation), especially those with two floors, reduced mosquito densities in homes compared with traditional sub-Saharan African homes (made with wattle-daub or mud-block construction, built on the ground with poor ventilation), that indoor temperatures were lower in houses adapted to tropical conditions than in traditional homes, and that residents’ and neighbours’ opinions were positive of the prototype houses. The findings show that is accepted by villagers in rural Tanzania to live in double storey buildings. Living in such buildings is more comfortable due to lower temperatures and reduced mosquito densities.

Implications of all the available evidence
Findings of observational studies have shown a strong association between house improvements (including metal roofs, closed eaves, eaves tubes, insecticide-treated curtains, and screened windows and doors) and reduced malaria transmission. However, such incremental improvements do not address the fundamental problems of the traditional rural African house design, namely poorly ventilated structures built on ground level. Elevating buildings insulates the living space from heat radiating from the ground and improves airflow, essential for a healthy air quality and a comfortable indoor environment, particularly in hot, humid climates. Our findings suggest it might be possible to decrease malaria transmission and improve comfort through changes in house design in hot humid climate zones in sub-Saharan Africa. Furthermore, improved ventilation might facilitate the use of bednets and reduce the transmission of respiratory tract infections. Added water harvesting and latrines might reduce the risk of enteric infections. Large randomised clinical trials are now needed to assess the clinical benefits and cost-effectiveness of modified house designs on malaria transmission and respiratory tract and enteric infections.

therefore important to keep the house cool. The climate “comfort zone” is a term used by physiologists and architects to describe the optimum combinations of temperature, humidity, and airflow that people find agreeable. Of these variables, airflow is of crucial importance but is often overlooked. In extremely hot and humid conditions even a small attenuation of airflow is sufficient to render a space uncomfortable, if not unbearable. Because airflow is reduced by about 60% in a space enclosed by a bednet, it is unsurprising that in tropical Africa insecticide-treated bednets are inconsistently used.

The traditional sub-Saharan mud hut is a wattle-daub (adobe) or mud-block construction, built on the ground with poor ventilation. By contrast, traditional rural homes in southeast Asia tend to be well adapted to the hot, humid climate. Houses are elevated on stilts and permeable materials such as bamboo slats are used for the construction of walls. Elevating the structure and using permeable walls promotes airflow, reduces the indoor temperature, and optimises the overall indoor climate. It is also likely that raising the house above ground level reduces the entry of *Anopheles gambiae* mosquitoes, the major African malaria vector, because most mosquitoes fly no more than 1 m above the ground.

Computational fluid dynamics modelling developed to predict indoor climate in contemporary urban structures within industrialised countries can be applied to rural housing in low-income countries. Such models predict improved indoor climate by elevating living spaces sufficiently to allow airflow under the house. Constructing houses with air-permeable building materials such as shade nets (a plastic fabric used primarily in agriculture to prevent excessive sun and rain exposure), loosely spaced timber planks or bamboo cladding and large, preferably screened, windows will facilitate airflow and cool the interior.

The design of residential buildings can have several health benefits (figure 1). For example, improved airflow and a lower indoor temperature make it more comfortable to sleep under a bednet, which could increase bednet use in malaria-endemic countries. Elevating houses can reduce indoor-mosquito densities and thus the risk of mosquito-borne diseases. Laying a floor compared with compacted earth reduces exposure to soil transmitted helminths. Separating wood burning stoves from living and sleeping spaces reduces indoor air pollution and
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