INDOOR DAMPNESS AND MOLD AS INDICATORS OF RESPIRATORY HEALTH RISKS, PART 4: HIGHER MEASURED MOISTURE IN HOMES WITH QUALITATIVE EVIDENCE OF DAMPNESS OR MOLD

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SUMMARY

Moisture measurements in the homes of participants in a birth-cohort study were evaluated for possible differences between readings on living room and bedroom walls, readings in homes with and without qualitative indications of dampness or disrepair (i.e., visible mold, visible water damage, a musty or moldy odor, or peeling paint), and readings on exterior (perimeter) and interior walls. Bedroom walls were statistically significantly damper than living room walls (p <0.0001), although measurements were positively correlated across room types (r = 0.58, p <0.0001); i.e., homes with drier or damper living rooms also tended to have drier or damper bedrooms. Measured moisture increased with the number of qualitative indicators of dampness/disrepair present in a home. Among single indicators, visible mold and musty odor were the most highly correlated with elevated moisture. Perimeter walls were damper than interior walls (p <0.0001), but interior walls next to bathrooms were not damper than interior walls next to rooms without plumbing.

INTRODUCTION

Many epidemiological studies have shown consistent associations between respiratory or allergic outcomes and qualitative indicators of indoor dampness or fungal growth, e.g., visible water damage, dampness, mold, or mold odor (WHO, 2009; Mendell et al., 2011). Two UK studies have reported statistically significant, dose-related increases in asthma symptoms with quantified home dampness as measured with a moisture meter (Williamson et al., 1997; Venn et al., 2003; Mendell, 2014). The findings in this paper are from the Center for the Health Assessment of the Mothers and Children of Salinas (CHAMACOS), a birth cohort study, that investigated the effects of environmental exposures on the health of low-income, predominantly Mexican-immigrant families in California. This work is part of a multi-component, ongoing effort at the Indoor Air Quality Section of the California Department of Public Health to develop evidence to support *quantitative*, health-protective guidelines for indoor dampness and dampness-related agents (Mendell et al., 2014).

We compared measured moisture in homes with and without the presence of qualitative indications of dampness/disrepair, assessed in 737 home visits when the children were 6 or 12 months of age. We hypothesized that measured moisture would be higher in homes with evident dampness or microbial growth and that dampness would be positively associated with the number of dampness/disrepair indicators present in a home. We also expected higher measured moisture in exterior, perimeter walls compared to interior walls and, among interior walls, in walls next to rooms with plumbing, such as bathrooms, kitchens, and laundry rooms. Given the age of the subjects, it was of interest to determine if bedrooms, where infants would be expected to spend most of their time, were damper than living rooms.

METHODOLOGIES

Trained inspectors systematically measured dampness with a pin-less, electronic resistance-type moisture meter (CT100, Electrophysics, Ontario, Canada). The moisture meter was designed to measure the moisture content of wood. When used on other materials, such as gypsum board, the unit of measurement is percentage wood moisture equivalent (%WME, the theoretical percentage moisture content of a piece of wood in moisture equilibrium with the material being measured) (Macher et al., 2014; Chen et al., 2014). Measurements were made on up to three walls in the living room (LR) and the child's bedroom (BR) 45–60 cm above the floor at the horizontal midpoint of a wall. Measurements were made first on all perimeter walls (exterior), second on inside walls next to bathrooms (interior/bath), and last on inside walls next to rooms without plumbing (interior). No measurements were made on walls next to rooms with plumbing other than bathrooms (i.e., none were next to laundry rooms or kitchens).

The inspectors also noted indications of dampness/disrepair in the homes, i.e., peeling paint, visible mold, visible water damage, mold odor, rotting wood, and leaking kitchen sinks. The indicators first were evaluated for their associations with measured moisture. Four of the six dampness/disrepair indicators were consistently positively associated with higher measured moisture, and the associations of these indicators with measured moisture were evaluated singly and in combination. Two room-specific maxima were determined for each home visit (HV), i.e., the highest reading in the LR and in the BR, as well as the overall maximum for each HV, i.e., the highest reading in a home. Geometric means (GM) and standard deviations (GSD) of moisture readings were reported. Correlation coefficients and two-sided Wilcoxon signed rank tests were used to compare paired moisture readings in LRs and BRs in the same homes. Two-sided Mann-Whitney U tests were used for comparisons of measurements in homes with and without qualitative dampness indicators and for comparisons of measurements made on exterior and interior walls.

RESULTS AND DISCUSSION

Moisture readings had a skewed distribution (Figure 1). Readings on bedroom walls were significantly higher than those on living room walls (p <0.0001), although living room and bedroom readings were positively correlated (r = 0.58, p <0.0001).

The most common qualitative indicators of dampness/disrepair were peeling paint and moderate to extensive mold anywhere other than in a bathroom, which were seen in 68% and 42% of 737 HVs, respectively. Less common were water damage (21%), a leaking kitchen sink (14%), a musty odor (11%), or rotting wood (9%). Homes were significantly damper in both rooms only if a musty odor, visible water damage, visible mold, or peeling paint was present (*p* = 0.02 to <0.0001).

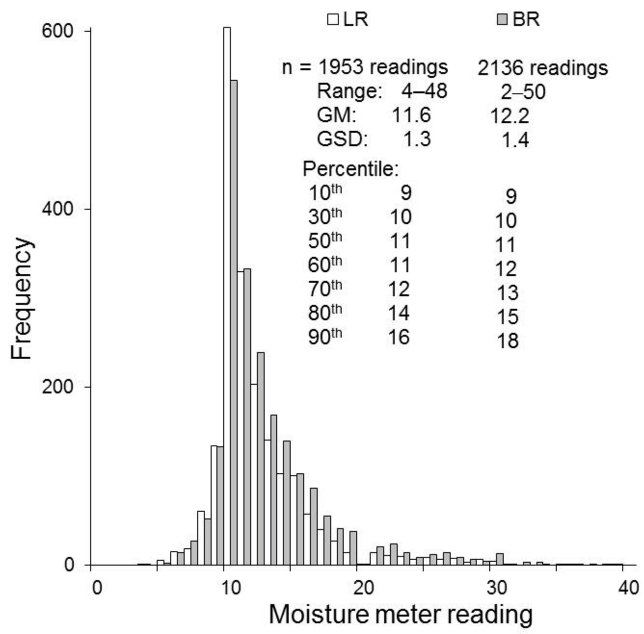

Figure 1. Frequency distributions of moisture meter readings in living rooms (LR) and bedrooms (BR).

All four of these indicators were seen in only 2% of homes, but these homes were among the dampest (GM: 19.5) and were similar to homes with the combination of peeling paint, visible mold, and a musty odor (GM: 19.8) (Table 1). Few homes had only a musty odor, but these were the dampest homes among those with only one indicator (GM: 16.3) followed by homes with visible mold (GM: 14.7) (Table 1). Moisture levels in homes with two indicators (GM: 16.3–17.5) and three indicators (GM: 16.3–19.8) were approximately similar for all but two combinations, i.e., peeling paint and water damage (GM: 14.7) and peeling paint, water damage, and a musty odor (GM: 13.0) (Table 1). Considering only the homes with three moisture measurements in both the BR and LR (N = 621 of 737 HVs), the more dampness indicators present, the higher the measured moisture (Figure 2).

Exterior walls were damper than interior walls but interior walls next to bathrooms were not damper than walls next to rooms without plumbing (Figure 3).

Work is underway to compare readings made with the moisture meter used in the CHAMACOS birth-cohort study and a meter used in a case-control study of English primary school children that found significant dose-related associations between asthma exacerbations and moisture readings in their homes (Venn et al., 2003; Chen et al., 2014; Macher et al., 2014; Mendell et al., 2014). The lowest category of measured moisture associated with increased health risks was 10–15 %WME (Venn et al., 2003; Mendell, 2014), which corresponded to ~60%–85% water activity, the upper range of which when sustained is sufficient for the growth of some fungi and bacteria (Chen et al., 2014; Macher et al., 2014). Dampness also supports biological agents other than microorganisms, e.g., insects and house dust mites, and may cause chemical or other changes in building materials that adversely affect health.

Table 1. Maximum measured moisture in homes with single and multiple dampness/disrepair indicators. For homes with multiple indicators, the asterisks identify the indicators observed.

Numbers of indicators (number of HVs, % of 737 HVs)	% of HVs in group	Overall maximum GM	Peeling paint	Visible mold	Water damage	Musty odor
No indicators (N = 112, 15%)	100%	12.3				
1 indicator (N = 330, 45%)	77%	13.9	*			
	21%	14.7		*		
	2%	11.6			*	
	<1%	16.3				*
2 indicators (N = 180, 24%)	49%	16.3	*	*		
	21%	14.7	*		*	
	12%	17.5		*		*
	9%	17.2		*	*	
	9%	17.1	*			*
3 indicators (N = 101, 14%)	73%	16.4	*	*	*	
	19%	19.8	*	*		*
	7%	16.3		*	*	*
	1%	13.0	*		*	*
All 4 indicators (N = 14, 2%)	100%	19.5	*	*	*	*

Abbreviations: GM, geometric mean; HV, home visit

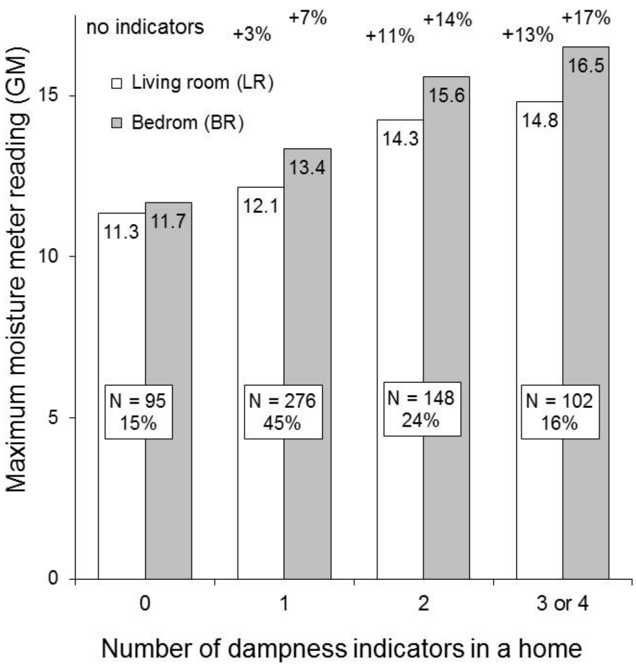

Figure 2. Comparison of the geometric means (GMs) of maximum measured moisture in homes with different total numbers of indicators of dampness or disrepair, i.e., peeling paint, visible mold, visible water damage, or mold odor; the percentages at the top of the figure are the respective increases relative to the same room type in homes with no indicators; N = number of home visits (HVs), percentage of 621 HVs.

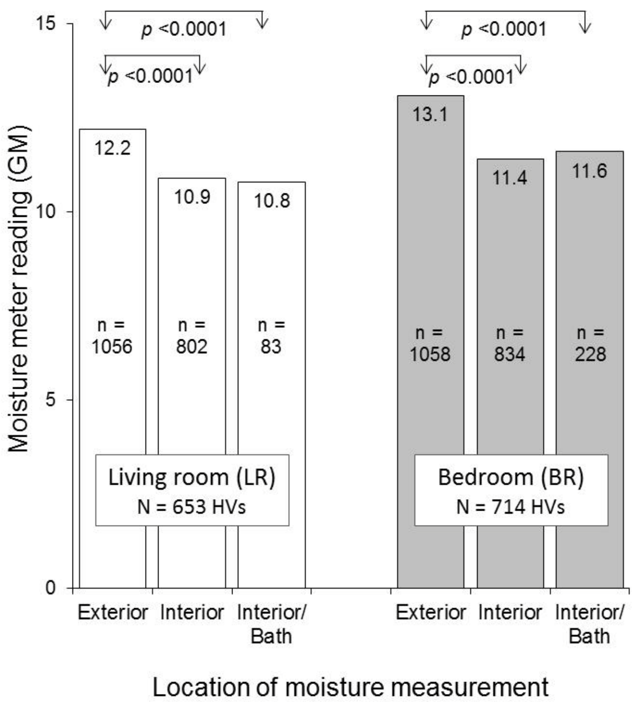

Figure 3. Comparison of the geometric means (GMs) of moisture readings at different measurement locations (information on location missing for 12 living room and 16 bedroom measurements); n = total numbers of measurements, N = number of home visits (HVs).

CONCLUSIONS

Infants may spend more time than other family members in their bedrooms, and the finding that bedroom walls were damper than living room walls indicates potentially greater exposure of infants to dampness-related agents. Visible mold, visible water damage, and a musty or mold odor have been associated with respiratory and allergic outcomes (WHO, 2009; Mendell et al., 2011; Jaakkola et al., 2013). That measured moisture was higher in homes with these indicators and that dampness increased with the number of indicators suggests that homes with visual or olfactory evidence of dampness are likely to be damper than homes that do not have signs of dampness or microbial growth. Our findings also demonstrated agreement between qualitative evidence of dampness, which may be subjective, and moisture measurements made according to a prescribed protocol, which were quantitative and objective.

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