Housing Characteristics and Leishmaniasis: A Systematic Review

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Abstract. Leishmaniasis is a major neglected tropical disease associated with high rates of disability and death. This disease is associated with poverty, which can be reflected in housing quality, especially in rural areas. This systematic review found that mud walls with cracks and holes, damp, and dark houses were risk factors for transmission of leishmaniasis. These characteristics create favorable conditions for sand fly breeding and resting as sand flies prefer humidity, warmth, and protection from sunlight during the day. Housing interventions might be a promising research area with a special focus on education as individual and collective protection for the effective control of leishmaniasis.

INTRODUCTION

Leishmaniasis is a major neglected tropical disease (NTD),¹ caused by more than 20 protozoa parasites of the *Leishmania* genus. It is transmitted to humans by the bite of infected female phlebotomine sand flies, resulting in three main forms of disease: cutaneous leishmaniasis (CL), visceral leishmaniasis (VL), and mucocutaneous leishmaniasis (MCL), with clinical manifestations ranging from skin ulcers to lethal systemic disease. The disease accounts for 900,000 to 1.3 million new cases and more than 20,000 to 30,000 deaths annually, with an estimated population at risk of more than 350 million people.^{2,3}

Leishmaniasis infections, like many other NTDs, are strongly related to poverty,^{4,5} and occur mainly in rural areas of developing countries,^{1,6} where populations encounter barriers for health care, sanitation, housing,⁷ and environmental changes such as deforestation,⁸ building of dams, and irrigation.⁹ Added to these factors, sand fly populations play a major role in leishmaniasis transmission. The abundance of phlebotomus correlates directly with the numbers of leishmaniasis cases.^{10,11}

One of the most widespread methods for sand fly control is indoor residual insecticide spraying^{12–14}; however, such measure becomes unsustainable over time,¹⁵ and even after spraying, the characteristics, including floor, walls, and roof materials, and quality of the house could hamper sand fly control.^{16,17}

Some specific housing characteristics have been associated with various health problems,^{7,18,19} including vector-borne diseases.^{20,21} “Unhealthy” houses are more frequent in rural areas, where leishmaniasis is more frequent. These houses are usually built by community members using traditional methods and short-lived natural materials found in the areas near the village (such as soil, mud, wood, straw, and leaves) using architecture and building technologies closely related to ancestral traditions.^{22,23}

Several studies have shown the relationship of vector-borne diseases such as malaria, dengue, and Chagas disease with traditional architectural practices and features of rural housing, including mud walls, thatched roofs, open eaves, and unscreened windows.^{24–28} In the case of leishmaniasis, information available about house-related risk factors is scarce.

The aim of this systematic review was to identify and describe housing risk factors for sand fly abundance or leishmaniasis and to assess the feasibility of using architecture or housing modifications as an option for reducing vector density and leishmaniasis.

METHODS

Literature search. A systematic search of published literature was performed in May to June 2016 using specific search terms for house characteristics, as well as vector and disease specific search terms. Medline and Lilacs databases were searched, with language restriction to English, Spanish, and Portuguese using medical subject headings and health sciences descriptors terms where appropriate. In addition, we reviewed cited and recommended lists of key articles. A search was conducted on vector (sand fly), cases of leishmaniasis, and house characteristics. More detail on the search terms used is provided in Table 1.

Inclusion and exclusion criteria. Studies that assessed house architecture association (e.g., wall, roof, and floor materials) or the effect of an architectural intervention on either clinical outcomes (prevalence or incidence of cases) and/or entomological outcomes (vector density or mortality) of leishmaniasis were included. Studies using impregnated nets or factory-manufactured nets were included when housing features were involved in the analysis. No restrictions were applied. We did not include peridomestic characteristics.

Data extraction and analysis. The results were categorized according to the source database and all duplicate entries were excluded. Those meeting the inclusion criteria were included for a full text review. The articles were separated into observational and intervention studies. The results were compared using two-way tables including housing modifications and clinical or vector density outcomes.

Quality assessment. The search was divided between R. C. and C. G. R. C. conducted the searches in Medline, C. G. consulted Lilacs. Each reviewer selected items using inclusion and exclusion criteria.

In a second step, R. C. reviewed abstracts of the articles selected by C. G. and vice versa, discarding items that did not meet specific inclusion criteria.

RESULTS

The systematic search identified 103 studies after removing duplicates; 37 met inclusion criteria and were assessed for eligibility. Six studies were excluded, two of the six included

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TABLE 1
Search terms

Source	Search term
Medline/PubMed	"Leishmaniasis"[mesh]/[all fields]
	"Housing"[mesh]/[all fields]
	"Psychodidae"[mesh]
	"Sand fly" [all fields]
	"House" [all fields]
SciELO	"Household" [all fields]
	"House characteristics" [all fields]
	"Leishmaniasis" [DeCS]
	"House"
	"Sand fly"
	"House characteristics"
	"Household"

housing features as part of an index and did not describe independent housing characteristics,^{29,30} three of the six commented on housing features only in the discussion,^{31–33} and only one described housing conditions as a possible intervention,³⁴ leaving 31 studies for the qualitative synthesis (Figure 1).

Fifteen of the 31 selected studies were conducted in Asia (9/15 in India), 11 in Latin America, and five in Africa. Most of the studies (23/31) were observational (cross-sectional or case-control), and 8/31 were intervention studies. The main outcome measure was clinical leishmaniasis cases in 22/31 studies, 15 (15/22) were focused on VL, whereas the other 7/22 in CL. In the remaining 9/31 studies, the main outcome was sand fly density using Centers for Disease Control and Prevention (CDC) light traps or mouth aspirators. Most of the studies were conducted in rural areas (27/31), 3/31 in the urban area and one was defined as semi-urban area.

Housing characteristics in observational studies. We identified 18/23 studies that reported a significant association between housing characteristics (e.g., walls, roof, floors, or windows) and leishmaniasis infection or sand fly density.

Wall characteristics. Sixteen of 18 studies found an association between leishmaniasis and wall type. In one of 16 studies, mud-plastered walls were associated with sand fly density—as defined by CDC light traps. This cross-sectional study compared houses with brick or plastered walls with mud walls in endemic VL villages in a rural area in India.³⁵

Fifteen of 16 studies found an association with clinical leishmaniasis: five of 15 with CL cases^{36–40} (all in rural areas); 10 of 15 were associated with VL cases^{41–50} (one from an urban area,⁴⁵ one from a semi-urban area,⁴³ and eight of 10 from rural areas).

Associated with CL cases. Two studies found that wood/cane versus cement/brick walls were associated with CL cases, both in Latin America: one in Ecuador⁴⁰ and the other in Colombia.³⁹ Another study conducted in Brazil found that walls made of nondurable material (not specified) were also associated with CL cases.³⁸

A study from rural Ethiopia found that walls with cracks and/or holes were environmental risk factors for CL,³⁷ whereas a study from Afghanistan found that brick or stone walls were associated with CL scars.³⁶

Association with VL cases. A study conducted in the semi-urban and rural area of Ethiopia found that individuals who lived in houses with cracked walls had six times increased odds of VL infection,⁴³ whereas a study carried out in an urban area of Nepal found that brick wall houses were protective

factors for VL when compared with thatched houses with no windows.⁴⁵

Eight studies were performed in rural areas. A study from India found that mud-plastered walls compared with cement-plastered houses were associated with VL⁴⁹; another study from India found that living in homes with mud walls increased the risk of VL infection by four times,⁴² whereas a study from Nepal found that houses constructed in mud were an independent risk factor for VL.⁴⁸ A study conducted in India found that thatch and/or mud compared with other materials, including bricks and cement plastering, significantly increased the likelihood of VL cases compared with the non-case households.⁴⁴ Another study from Kenya found that houses constructed from mud and sticks were significantly associated with VL seropositivity.⁴⁷

A study from India found thatched houses were associated with VL, independently from socioeconomic status.⁴¹ A study from Kenya found that the frequency of VL positivity was higher in individuals living in wood houses than those living in houses with mud or stone walls. This difference was significant only for females and children.⁵⁰

Last, a study from India specified the house type rather than a specific material, dividing it into kutchha, referring to inferior materials usually mud, thatch, or other low-quality materials; pucca, referring to strong, high-quality materials; and semi-pucca, a combination of both. This study found that VL was most significantly prevalent in kutchha houses than in semi-pucca or pucca houses.⁴⁶

Other housing characteristics. Other associated factors included floor/house dampness (3/23), absence/permanent opening of windows (2/23), screened window (1/23), and ceiling materials, including corrugated iron (1/23) and wood beamed ceiling (1/23), the latter found to be a protective factor.

Specific measures of association between housing characteristics and outcome variables are described in Table 2.

Six studies did not find wall type/quality associated with leishmaniasis (five VL and one CL). House floor dampness was also not associated in one studies, whereas roof material, including thatched roof/ceiling was not associated in five studies, although three of these studies did find an association with wall characteristics.

Specific measures of studies that did not find housing characteristics associated with the outcome variables are described in Table 3.

Housing characteristics in intervention studies. We identified eight intervention studies describing housing characteristics, including clinical trials, experimental, and pilot studies. The main outcome measured in this category was sand fly density captured by light traps (5/8) and sand fly mortality by wall bioassay (3/8), unlike the observational studies that included mostly leishmaniasis cases.

One experimental study evaluated the role of the wall openness in experimental chicken sheds made of plywood walls with doors and palm thatch roofs, evaluating completely closed, 12.5% and 25% open walls and finding a significantly higher number of sand flies in open sheds.

Four studies evaluated the effect of insecticidal spray on different wall materials, 1/4 evaluated sand fly density, finding differences associated with housing quality, destitute houses had disproportionately larger sand fly abundance, and in some cases, the number was higher even after insecticide thermal fogging.

FIGURE 1. Flowchart of studies included.

The remaining three of four studies evaluated wall bioassay mortality. One study evaluated fogging on cement wall versus oil-painted wall, finding no significant differences in sand fly mortality at 7 or 125 days after fogging, whereas it was significantly higher in oil-painted wall at 69 days. Another study matched houses according to their structure: mud and straw, concrete, and wood that were randomly assigned to spray treatment or control. This study found that sand fly mortality decreased progressively on wood and cement surfaces after 63 days compared with a more rapid decrease on mud and straw walls, and after 131 days, wood surface showed the best

residual effect. The third study evaluated spray on the external and internal surfaces of three types of walls: rough adobe without plastering, plastered with adobe (not painted), and plastered with adobe and a lime base paint, finding that mortality rates were similar, whatever the type of wall since the fourth month.

Three studies evaluated the effect of plastering and closing crevices with a mixture of mud and lime; one found no significant difference in sand fly density, whereas the other two found a decrease in sand fly density after the intervention. Studies are summarized in Table 4.

TABLE 2
Studies that found housing characteristics associated with leishmaniasis infection or sand fly density

Author, year	Country	Main population	Outcome	Findings/exposure	Adjusted OR (CI 95%)
Bsrat et al., 2015	Ethiopia	Rural	CL lesions/scars or parasitological confirmed	Walls with cracks and/or holes	4.04 (1.77–9.22)*
Yared et al., 2014	Ethiopia	Semi-urban/rural	VL cases previously diagnosed	Cracked house wall	6.37 (1.59–25.58)
Uranw et al., 2013	Nepal	Urban	VL cases	Thatched house with windows	0.36 (0.15–0.84)
				Brick house	0.26 (0.09–0.73)
Perry et al., 2013	India	Rural	VL cases previously diagnosed	Thatched and/or mud house	6.59 (1.83–23.69)*
Singh et al., 2010	India	Rural	VL cases parasitologically confirmed	Thatched walls	2.60 (1.50–4.48)
				Brick walls with no windows	2.38 (1.20–4.72)
				Damp floor	2.60 (1.25–5.41)
Reithinger et al., 2010	Afghanistan	Rural	CL clinically diagnosed based on lesions/scars	Brick wall type	1.32 (1.02–1.71)
				Stone wall type	1.24 (1.01–1.52)
				Wood-beamed ceilings	0.64 (0.50–0.83)
Kesari et al., 2010	India	Rural	Sand fly density captured by CDC light trap	Mud-plastered wall	1.71 (1.33–2.20)
Boelaert et al., 2009	India	Rural	Highly endemic clusters reported in the past 3 years	Kutcha	6.59 (5.82–7.48)
				Semi-pucca	0.44 (0.38–0.49)
				Pucca	0.13 (0.11–0.16)
Saha et al., 2009	India	Rural	Seropositivity in a previously negative patient in a direct agglutination test	Mud walls	RR: 4.3 (1.6–11)
Pedrosa and Ximenes, 2009	Brazil	Rural	ACL lesions/scars or parasitologically confirmed	Damp residential rooms	RR: 2.5 (1.7–3.7)
				Nondurable wall material	2.42 (1.10–5.32)
Rodríguez-Villamizar et al., 2006	Colombia	Rural	Scar/lesions present in less than 10-year-old children	Wooden walls	PR: 2.47 (1.59–3.96)
Ryan et al., 2006	Kenya	Rural	Seroprevalence determined by ELISA	Sticks and mud houses	5.5 (2.4–12.5)
Schenkel et al., 2006	Nepal	Rural	Direct agglutination test $\geq 1:3,200$	Mud houses	3.0 (1.1–7.6)
Ranjan et al., 2005	India	Rural	Clinically and parasitologically confirmed kala-azar patients	Mud-plastered walls compared with cement-plastered houses	2.4 (1.5–3.8)
Yadon et al., 2003	Argentina	Rural	ACL previously diagnosed or parasitologically confirmed	Permanent opening for window	5.3 (2.4–11.7)
				1–3 rooms compared with more	5.0 (2.3–11.1)
				Mud vs. cement floor	5.0 (1.1–5.0)
				Permanent opening for main entrance	3.4 (1.6–7.2)
				Corrugated iron roof	2.9 (1.2–7.3)
Bern et al., 2000	Nepal	Rural	Clinically and parasitologically confirmed VL patients	House floor dampness	4.4 (1.7–11.4)
Armijos et al., 1997	Ecuador	Rural	Clinically and parasitologically confirmed CL patients	Wood and/or cane wall compared with cement blocks or bricks walls.	1.77 (1.38–2.53)
Schaefer et al., 1994	Kenya	Rural	Leishmanin skin test	Females living in wood houses compared with mud or stone walls houses.	PR: 1.38 (1.22–1.55)

ACL = anthroponotic cutaneous leishmaniasis; CI = confidence interval; CL = cutaneous leishmaniasis; ELISA = enzyme-linked immunosorbent assay; OR = odds ratio; PR = prevalence ratio; RR = relative risk; VL = visceral leishmaniasis.

* Crude OR, multivariate analysis not performed.

DISCUSSION

Most leishmaniasis cases are concentrated in Africa, America, and the Southeast Asia⁵¹ where they share, among others, similar housing characteristics, especially in rural areas.^{52–55} This study systematically assessed several common housing features as risk factors for this disease.

The most frequent housing material used in these areas was mud. Even after plastering, mud structures are more prone to cracks and holes,⁵⁶ that provide optimum breeding sites and resting places to sand flies, offering warmth and protection from sunlight.^{49,52,53,57} Mud walls can also retain moisture for prolonged periods after the rainy season, providing temperature and humidity favorable for sand fly presence.^{31,58,59}

Despite finding 15 studies that identified wall type/quality associated with leishmaniasis, five studies did not, three of five identified “sleeping outside” or “nocturnal outside activities” as risk factors.^{60–62} Taking into account the nocturnal biting habits of the sand flies,⁶³ this could explain why the housing characteristics in this communities did not represent a major risk, highlighting the importance of sleeping habits along with the avoidance of outdoor evening activities and outdoor biting.

In the remaining two of five studies that did not find an association with wall characteristics, selection bias might have occurred. In one study, controls were taken from an electricity company roster; despite probable higher socioeconomic status for households with electricity, researchers stated that controls did not differ substantially from the overall population.

In this study, the inadequate sewage system and/or no regular rubbish collection appeared to be particular risks factors for developing VL.⁶⁴ Meanwhile, in the other study, some data regarding wall features were missing, but despite this, house floor dampness to touch was a strong risk factor in the multivariate analysis.⁶²

Floor dampness was identified in three studies as a major independent risk factor^{41,42,62}; the distribution and abundance of sand flies has been studied and attributed to environmental factors such as rainfall, temperature, and humidity,^{31,65} which correlates with our findings, showing that houses with damp floors could provide the adequate needs for the vector survival.

In terms of roof materials, four studies did not detect an association. This could be due to the flying patterns of the sand flies; Gaglio et al.⁶⁶ described that sand fly density collected at 50 cm above ground was 3.6 times higher than that captured at 150 cm. Faiman⁶⁷ conducted an experiment showing that traps suspended just above the ground level captured 87% of sand flies, at 1 m above the ground 11%, and traps set at 2 m captured only 2% of the sand flies. Similar results were obtained in the same study, using sticky surfaces on a vertical wall with significantly more sand flies on the lower sections of the wall than on the higher ones, suggesting a low ground flying pattern and preference could be related to the finding that roof or ceiling materials did not represent a risk factor.

Another housing feature associated with higher presence of sand flies and leishmaniasis was windows—which were a risk

TABLE 3
Studies that did not find association between housing characteristics and leishmaniasis infection or sand fly density

Author, year	Country	Main population	Outcome	Findings/exposure	Adjusted OR (CI 95%)
Nackers et al., 2015	Sudan	Rural	Clinical and rapid test and/or a direct agglutination test VL cases	Many cracks in the room's wall made of either strong mud, plastered or unplastered cane	1.49 (0.98–2.25)
Yared et al., 2014	Ethiopia	Semi-urban	VL cases previously diagnosed	Separate kitchen Damp house floors Thatched roof	0.53 (0.32–0.89)* 4.33 (2.10–8.93)* 0.90 (0.52–1.55)*
Votýpka et al., 2012	Turkey	Rural	CL lesions/scars or previously diagnosed	Concrete house Plastered walls	1.37 (0.79–2.40)* 0.86 (0.48–1.57)*
Reithinger et al., 2010	Afghanistan	Rural	CL lesions/scars or previously diagnosed	Thatched wood ceiling	0.85 (0.53–1.36)
Kesari et al., 2010	India	Rural	Sand fly density captured by CDC light trap	Thatched roofs	1.60 (1.14–2.25)*
Castro et al., 2005	Brazil	Urban	Serological test for VL	Plastered wall Mix plastered/unplastered wall	1.2 (0.4–4.0) 2.3 (0.6–9.0)
Costa et al., 2005	Brazil	Urban	VL cases previously diagnosed	Inadequacy of the following: Ceiling Roof Floor Walls	 1.57 (0.43–5.66) 1.79 (0.26–12.30) 2.38 (0.68–8.30) 2.36 (0.96–5.80)
Barnett et al., 2005	India	Rural	VL cases previously diagnosed	Mud-plastered floor Mud-/unplastered wall Thatched/tile roof	 $P = 0.146^\dagger$ $P = 0.112^\dagger$ $P = 0.067^\dagger$
Bern et al., 2000	Nepal	Rural	VL cases previously diagnosed.	Cracks inside walls of house Cracks outside walls of house	2.3 (1.1–4.8)* 2.5 (1.2–5.6)*

CL = cutaneous leishmaniasis; OR = odds ratio; VL = visceral leishmaniasis.

* Crude OR, adjusted OR not available.

† Adjusted OR not available.

factor if the window space was permanently open,⁶⁸ allowing an easy access for sand flies, but also, if there was no window.⁵² The latter could be due to the dark environment that protects sand flies from sunlight⁶⁹ as well as high humidity, which is preferred by the vector.⁷⁰ Screened windows that allowed light to enter, humidity to exit, and at the same time prevented sand flies entering have demonstrated a protective factor against leishmaniasis infection.⁵⁹

Data on intervention studies were scarce. For insecticidal spraying, the best wall material appeared to be wood,⁷¹ as previously reported and recommended by WHO,⁷² mainly because of its nonabsorbent surface—allowing a prolonged effect of the insecticide. This also explains the failure of rough and absorbent surfaces such as mud or unpainted adobe. These materials can also increase pH, causing more rapid breakdown of some insecticides.⁷²

Three studies focused on wall repairing interventions, two found a significant reduction on sand fly density after house plastering with a mixture of mud and lime.^{73,74} Plastering could reduce the numbers of cracks and holes in the walls, which are risk factors as described previously. In spite of this, one study found that mud plastering without lime could not reduce the sand fly abundance.⁷⁴ Furthermore, mud plastering has been reported as a risk factor.⁴⁹ In this study, wall plastering was performed by the heads of household, promoting the continuing filling of cracks and crevices. We hypothesize that the different results obtained after mud plastering could be due to differences in the plastering technique; as previously described, mud tends to create holes and cracks after drying,⁵⁶ which highlights the need to reinforce mud to prevent this process. That could be accomplished by adding other materials such as straw or sand that make mud more compact, which would improve mud quality.⁷⁵

Lime mixtures could provide an extra benefit when plastering, creating an unfavorable environment for vectors, and

acting as a toxin for sand fly larvae, as reported in some studies⁷⁴; in the same way, lime has shown great potential for stabilizing soil, to improve its construction properties.^{76–78} When lime is added to soil, it alters its chemical properties, increasing cation exchange and thus making soil particles attract each other.⁷⁹ This could be helpful when closing crevices and cracks, creating a solid and strong mixture for plastering. In addition, lime has been used as a drying method in wet environments.⁸⁰ As previously established, reducing humidity could also aid in the control of sandflies.

There is a lack of information on lime use in wall plastering for the prevention of leishmaniasis, and its use is still controversial, with results in both directions.^{73,81}

We found that leishmaniasis is a multifactorial problem, where housing characteristics may play a key role. These characteristics have been demonstrated to be independent risk factors for this disease, but there are still major research gaps. Further studies involving house characteristics are needed; these studies should involve multidisciplinary teams, including health-care professionals, architects, and engineers to identify risk and to develop new methods of construction using materials accessible in rural areas. Likewise, future interventions should be developed with participation of the community with emphasis on health education as well as housing improvement as individual and collective protection for the effective control of leishmaniasis.

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TABLE 4
Intervention studies related to housing characteristics associated with leishmaniasis infection or sand fly density

Author, year	Study type	Main population	Country	Intervention	Evaluation times	Outcome measure	Findings
Chaves et al., 2013	Controlled trial	Rural	Panama	Indoor and outdoor insecticide thermal fogging.	Monthly for 9 months	Sand fly density by modified light traps	Destitute houses had a larger sand fly abundance, some with increased domiciliary sand fly after the fogging
Joshi et al., 2009	Cluster randomized controlled trial	Rural	Bangladesh, Nepal, and India	Wall plastering with mud and mud/lime mixture.	Pre- and postintervention	Sand fly density by CDC light traps	Mud wall plastering was not effective; lime plastering significantly reduced the sand fly densities
Das et al., 2008	Cluster randomized controlled trial	Rural	Nepal	Cracks, crevices, and other potential sand fly breeding and resting places repaired with lime.	2 weeks before, and 2, 4, and 20 weeks after the interventions	Sand fly density by CDC light trap and mouth aspirator	No significant difference in vector density while comparing with the control arm
Feliciangeli et al., 2003a	Controlled trial	Rural	Venezuela	Intradomestic residual spraying and spatial fogging on cement walls vs. oil-painted walls	7, 69, and 125 days after spraying	Wall bioassay of sand fly mortality	Sand fly mortality was significantly higher in oil-painted wall at 69 days
Feliciangeli et al., 2003b	Controlled trial	Rural	Venezuela	Spraying vs. control, stratified by construction material: Mud and straw, concrete, and wood.	8, 63, and 131 days after spraying.	Wall bioassay of sand fly mortality	Wood surfaces showed more residual effect after 131 days.
Silans et al., 1998	Trial	Rural	Brazil	Spray on: rough adobe without plastering, plastered adobe (not painted), and plastered adobe and lime base painting.	Monthly for 5 months.	Wall bioassay of sand fly mortality	Sand fly mortality decreased rapidly in mud and straw walls
Kumar et al., 1995	Pilot study	Rural	India	Plastering with a mixture of mud and lime.	Pre- and postintervention	Sand fly density	Residual activity remained high the first 3 months in plastered unpainted walls. Sand fly mortality rates were identical whatever the type of wall since the fourth month
Quinnell and Dye, 1994	Experimental	Rural	Brazil	Openness of the walls in experimental chicken sheds, evaluating closed, 12.5% and 25% open walls.	Every two to three nights for six to nine times	Sand fly density by CDC trap without a bulb	Sand fly density decreased in treated houses
							Closed sheds caught almost no sand flies and significantly fewer than the open sheds

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