Indian J Med Res 138, August 2013, pp 239-243

User friendliness, efficiency & spray quality of stirrup pumps versus hand compression pumps for indoor residual spraying

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Received February 8, 2011

***Background & objectives*: Indoor residual spraying (IRS) is a proven tool to reduce visceral leishmaniasis vectors in endemic villages. In India IRS is being done with stirrup pumps, whereas Nepal, Bangladesh, and other countries use compression pumps. The present study was conducted with the objectives to compare the efficiency, cost and user friendliness of stirrup and compression pumps.**

***Methods*: The study was carried out in Gorigawan village of the Vaishali district in north Bihar and included a total population of 3259 inhabitants in 605 households. Spraying with 50 per cent DDT was done by two teams with 6 persons per team under the supervision of investigators over 5 days with each type of pump (10 days in total using 2 stirrup pumps and 3 compression pumps) by the same sprayers in an alternate way. The spraying technique was observed using an observation check list, the number of houses and room surfaces sprayed was recorded and an interview with sprayers on their satisfaction with the two types of pumps was conducted.**

***Results*: On average, 65 houses were covered per day with the compression pump and 56 houses were covered with the stirrup pump. The surface area sprayed per squad per day was higher for the compression pump (4636 m^2) than for the stirrup pump (4102 m^2). Observation showed that it was easy to maintain the spray swath with the compression pump but very difficult with the stirrup pump. The wastage of insecticide suspension was negligible for the compression pump but high for the stirrup pump.**

***Interpretation & conclusions*: The compression pump was found to be more user friendly due to its lower weight, easier to operate, lower operation cost, higher safety and better efficiency in terms of discharge rate and higher area coverage than the stirrup pump.**

Key words Compression pump - indoor residual spraying - stirrup pump - vector control - visceral leishmaniasis

Indoor residual spraying (IRS) is a process of spraying the inside of dwellings including houses and cattle sheds with an insecticide to kill or repell target insects such as mosquitoes or sand flies that spread diseases such as malaria, filariasis, kala-azar and others. A diluted solution of insecticide is sprayed on the inside walls or in and around the houses of certain types of dwellings where the disease vectors can hide or rest. The most essential equipment in IRS is the spray machine.

Hand pumps have a long history of use in agriculture and public health activities, and as a result of the Industrial Revolution, the hand operated tank pump fuelled the development in the fight against insect pests[1]. One of the most renowned versions of the machine was a small hand-operated pump called stirrup pump: the stirrup-shaped base was placed in a bucket of water, a small hose could direct a stream onto small fires[2]. This simple equipment was initially used by the British fire defense department. The name 'stirrup pump' came quickly into general use[1]. A hand compression pump sprayer consists of a tank for holding a liquid insecticide formulation, which can be pressurized by means of a hand pump attached to it. The compressed air forces the liquid from the tank via a hose with a cut-off valve, a lance and a nozzle[3]. With the adoption of the basic design and further development, the hand operated tank pump was widely used for insecticide spraying particularly in the Indian subcontinent.

Vector control measure including insecticide spraying should be strategic approach for the kala-azar elimination programme[4]. In India, visceral leishmaniasis (VL) is endemic in 52 districts[5], where indoor residual spraying (IRS) is being conducted by the National Vector Control Programme with the stirrup pump, because it was, for a long time, less costly than the compression sprayer[6]. Recent studies showed that IRS is a powerful tool to reduce vector density if it is carried out under well controlled conditions[7]. It has been reported earlier that spray of insecticides for reduction of sand flies will add to rapid elimination of disease[8]. When IRS is used in national programmes however, it is less effective partly due to poor performance of the stirrup pump[9].

IRS can be conducted either with stirrup or compression pumps. In an analysis of the IRS programme in Bihar, India, several shortfalls were identified with stirrup pumps regarding the coverage and quality of IRS[8]. Therefore, the present study was carried out to compare the user friendliness, efficiency and spray quality of conventional stirrup pumps versus hand compression pumps in terms of number of houses sprayed and area covered per day, maximum utilization of insecticides (with low wastage of insecticides) and the operational feasibility of both pumps. A secondary objective was to determine the number of houses or surface areas which can realistically be sprayed per day compared to national norms in India.

Material & Methods

The study was conducted by the Rajendra Memorial Research Institute of Medical Sciences (RMRIMS), Patna, India. Written consent was obtained from study house holds (HH) who were willing to participate in the study. Ethical approval was obtained by the RMRIMS review board and by the WHO-Ethical Review Committee.

Selection of the study area: The study was carried out in Gorigawan village under (Sub centre-Gorigawan) Mahua Primary Health Centre (PHC) of the Vaishali district in north Bihar which had the highest number of reported VL cases in previous years (*Source*: Primary Health Centre, Mahua, Vaishali). The village had 3331 inhabitants living in 663 households. The work was started from April 20-24, 2010.

Sensitization and community awareness: In order to simulate a high quality IRS programme, the following pre-spray activities were carried out: A sensitization meeting was conducted with the District Malaria Officer (DMO) and Medical Officer In-Charge (MOIC) and other relevant public health staff to receive approval and logistic support for the study. The community was informed through canvassing and loud speakers mounted on a vehicle two days before the spraying was performed. On the day of spraying, the research team together with the spray team asked the household (HH) members to remove all utensils, cloths, food and livestock such as ducks, chicken and cattle from the dwellings.

Training of spray men and supervisors: One day training was organized for 12 spray men and their supervisors regarding the objectives of the study and IRS with the two types of pumps.

Equipment and personal protection equipment: The following equipment was procured by the study team: two stirrup pumps (manufacturer: Beta Engineers, Mamurpur, Narela, Delhi) including buckets, containers with pound measure, gallon measure and three locally manufactured compression pumps (manufacturer:

Orion Engineering Works, Khanna, Punjab). Stirrup pumps had no holding tank and no pressure gauge but had a 15 liter capacity bucket for the insecticide; the compression pumps had a 9 liter capacity holding tank and a pressure gauge. The cost of a complete stirrup pump was ₹2558.10 (USD 55.55) and the compression pump was ₹2763 (USD 60) (Table).

Strainer, pen, and ink for stencil cutting on the walls were also provided. The spray teams received personal protection equipment (PPE) such as caps, goggles, mask, apron and gloves and standard register forms to keep proper spraying records.

Formation of spraying squads: Two squads were formed (one with two stirrup pumps and one with three compression pumps), each with six persons similar to the national IRS programme. In the teams with stirrup pumps, four persons were engaged as spray men, one as a mixer of the insecticide and one person for maintaining the register and marking stencils on the entrance of sprayed houses. For the compression pump, three persons were engaged in spraying with three pumps, two persons in making the solution and one (called senior field worker, SFW) maintained registers and marked stencils. Every alternate day the teams were asked to exchange pumps so that the team which was using compression pumps was given stirrup pumps and vice versa. The DDT (WP 50%) was provided by Mahua, PHC. The spray operation every day started from 1000 h with 1 h lunch break and work continued till 1730 h as in the national IRS programme.

Research activities: The spraying activities were observed by the researchers together with PHC staff in four randomly selected houses per day for each type of pump for five days operation (stirrup pump-20 houses and compression pump-20 houses). In five days IRS operation, the total number of 280 houses (population-1438) and 325 houses (population-1788) were sprayed by stirrup and compression pumps respectively. The preparation of DDT suspensions and IRS procedure was observed; particularly the swath formation, distance of nozzles from the wall, discharge rate of nozzle and others (Table). Additionally, the coverage of spraying by each type of pumps was assessed. The 12 spray men were interviewed after completing the 5 days of work about their satisfaction with the two types of pumps in a formal interview applied by the researchers.

Table. Comparing stirrup and hand compression pumps

Statement	Stirrup pump	Hand compression pump
Spray machine		
– Tank capacity	15 l	9 l
– Pressure gauge	Not required	Required
Observation		
– No. of pumps used in one squad	2	3
– Persons in one squad	6 (5 spray men† + 1 SFW*)	6 (5 spray men† + 1 SFW*)
– No. of strokes	23 - 27/min	20 in initial stage
– Nozzle discharge rate	650 - 750 ml/min	750 ml/min
– Stirring	Required while spraying	Not required
– Time required to empty one tank (in min)	30 – 40	20 - 25
– Wastage of insecticide suspension (DDT)	100 - 200 ml/pump	Negligible
Spray men satisfaction with pumps		
– Easy to operate	Difficult (92%; n=12)	Easy(100%; n=12)
– Easy to carry	Not required	Easy (92%; n=12)
– Spray swath	Difficult to maintain (100%; n=12)	Easy to maintain (100%; n=12)
– Area/household covered by per squad/day	4102 m^2	4636 m^2
– Accuracy of DDT solution release	Not uniform (100%; n=12)	Uniform‡ (100%; n=12)

*SWF, Senior Field Worker; †Spray men designated as Field Worker (FW), so that they have been assigned for spraying, prepare insecticide solution, maintain registers and marked stencils by rotation. Which mean all five FWs performed three above-mentioned activities; ‡When pressure generated (40 PSI or 2.8 kg/cm^2) in the tank maintain a uniform spray pattern and swath width (53cm or 21") and with flat fan spray nozzle it provides 750-850ml/minute discharge

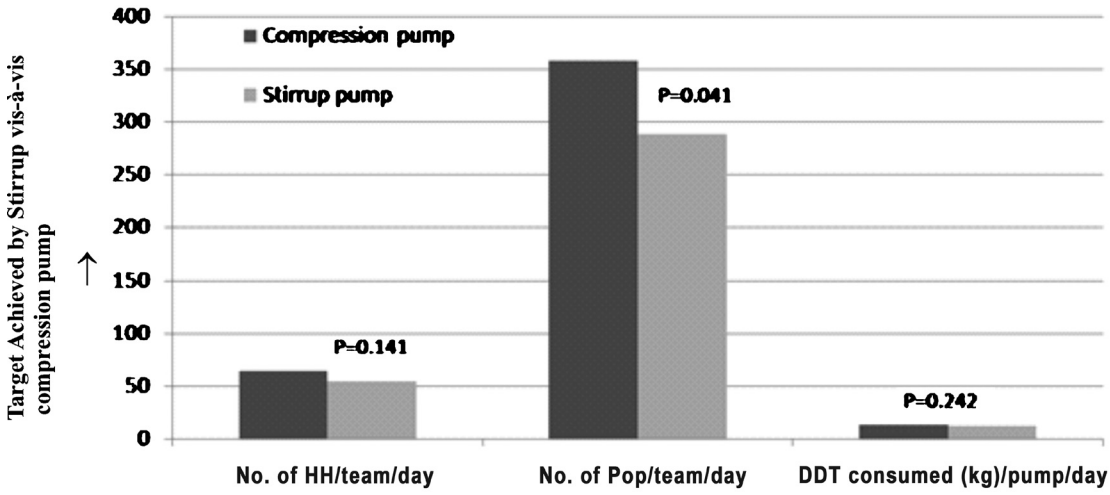

Fig. The major achievements of the spraying, activities with stirrup and compression pumps. HH, households; Pop, population.

Sample size considerations: Assuming that the average population coverage achieved would be 40 persons (SD 8) with the stirrup pump and 60 persons (SD 7) with the compression pump per pump per day, the minimum sample size of comparing the performance of four pumps each will achieve 80 per cent power to detect a difference of 20 population coverage per pump per day with a 5 per cent level of significance using a two-sample t-test. The estimated sample size was 8 pumps (4 versus 4) but we observed 10 pumps which gave sufficient power to the study (2 stirrup pumps plus 3 compression pumps were observed twice, based on our previous experience (Kumar *et al*, unpublished data) that to observe the performance of four pumps in one time or two pumps twice showed no significant difference of the results).

Data management and statistical analysis: All data were entered into a computer by using EPI INFO software (Centres for Disease Controll and Prevention Atlanta, GA). Descriptive statistics were applied and 95% confidence intervals (CI) were calculated assuming normal distribution. Comparison of mean statistics was done parametrically using independent t-tests. The data analysis was done in STATA 10.

Results

In the IRS operation, 9.3 houses/pump/day (95% CI, 6.2 - 12.3) were sprayed with the stirrup pumps and 10.8 houses/pump/day (95% CI, 8.9 - 12.8) with the compression pumps (Figure). With the stirrup pump, a population of 47.9 persons/pump/day (95% CI, 38.1 - 57.8) and with the compression pump, a population of 59.6 persons/pump/day (95% CI, 50.7 - 68.5). respectively ($P<0.05$) was covered. The average surface area sprayed by one squad per day with the two stirrup pumps was 4102 m^2 (corresponding to 56 houses) and 4636 m^2 (corresponding to 65 houses) with the three compressor pumps. A total of 58.1kg DDT (95% CI, 51.2 - 64.9) and of 62.0 kg (95% CI, 57.6 - 66.5) was used with the stirrup and compression pump, respectively (Figure).

One 15 liter bucket of the stirrup pump required 30 - 40 min for completion and one fill of the nine liter tank of the compression pump required 20 - 25 min for completion. On average, 2.35 min were required to spray one liter DDT solution with the stirrup pump (with 2 spray men for each pump) and 2.5 min for spraying one liter with the compression pump (one spray man per pump).

The discharge rates for both the pumps were found to be 650 – 750 ml/min, which is required to get 1 g DDT per m^2 on walls. The number of pump strokes per min was 23 - 27 for stirrup pumps during the entire spraying process and only 20 strokes per compression pump at the beginning which was sufficient for four houses. It was observed that with the stirrup pump, due to the irregular and often large number of strokes, 45 - 50 strokes per min were sometimes used resulting in a discharge rate higher than 950 ml/min leading to an overspray. This was not the case with compression pumps. Another disadvantage of the stirrup pump was that it required frequent stirring, which was not the case for compressor pumps. Also, 100 to 200 ml insecticide solution was wasted after each spraying and emptying of the bucket with the stirrup pump. In

contrast, wastage was negligible in the compression pumps (Table).

The interviews with the 12 spray men regarding their satisfaction with the two pump types showed that the stirrup pump was difficult to operate and particularly to maintain the spray swath whereas it was easy with the compression pump. It was also mentioned that the compression pump was easier to carry than the stirrup pump.

Discussion

It has been shown that IRS is an effective tool to reduce VL vector densities in endemic communities in the Indian subcontinent[5]. The spray pump is the most important equipment to achieve a high quality spray without insecticide wastage in the highest possible number of houses.

Our study showed that *(i)* The same number of squad members covered more houses and surface areas with compression pumps compared to stirrup pumps. *(ii)* The minimum number of houses to be sprayed per day per squad according to national norms in India is 60-70 HHs[3]. This is achievable with compression pumps (65 houses per squad per day) but not with stirrup pumps (56 HHs per day). *(iii)* Although the cost of a new stirrup pump was slightly less than that of a compression pump, the cost per house sprayed was lower for the compression pump as more houses could be sprayed by the same number of staff compared to the stirrup pump. *(iv)* Insecticide wastage was high for the stirrup pump and almost negligible for the compression pump. *(v)* The compression pump was easier to carry around and facilitated a better application of the DDT on the wall compared to the stirrup pump.

One squad can operate only two stirrup pumps but three compression pumps. The compression pump also has the advantage that the insecticide suspension is kept in a close vessel. The stirrup pump is operated by two persons (one person for spraying and the other person pumping) and the pipe from the bucket to the sprayer is approximately 5.4 m (18 feet) long causing a gap between start and stop of spraying which usually spoils some DDT suspension. Moreover, the frequent removal of the stirrup pump from the bucket and replacing it back into the bucket further increases loss.

In conclusion, the compression pump showed several major advantages compared to the stirrup pump in terms of efficiency (spray coverage, population coverage, no. of houses sprayed and total DDT used per house), user friendliness (lower weight, easier to operate, higher safety than that of stirrup pumps) and better discharge rate.

Acknowledgment

The authors acknowledge the participation of study subjects and villagers during the study period. We are grateful to all public health employees including spray men for their support in the field activities. The study was carried out at RMRIMS, Patna, Bihar State. RMRIMS acknowledges with gratitude the commitment of UNICEF /UNDP/ World Bank /WHO for research efforts and the Special Programme for Research and Training in Tropical Diseases (TDR/WHO) for financial support.

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