Spatial and Kinetic Factors for the Transfer of Head Lice (*Pediculus capitis*) Between Hairs

Deon V. Canyon, Richard Speare, and Reinhold Muller

Affiliation: School of Public Health & Tropical Medicine, James Cook University, Townsville, QLD 4811, Australia

Although the global increase in pediculosis is well known, little is known about the exact nature of head lice (*Pediculus capitis*) transmission. Several mechanisms have been proposed such as head-to-head and fomite transmission, but some contention remains concerning the primary transmission route. This study investigated spatial and kinetic factors influencing the dynamics of hair-to-hair transfer to clarify further how head lice transmit from head to head. Forty-eight factorial experimental trials, with 10 replicates each, were conducted using 480 freshly caught *P. capitis* from primary school children. In the trials, each louse was placed on a stationary suspended hair or a mobile hair and was presented with mobile or stationary hairs for transmission. All hair passes involved contact between the uninhabited hair and the lice. Hairs without a louse were presented dorsally, laterally, and ventrally to the louse. They were also passed from head to tail or from tail to head and were moved at speeds of 8 m and 4 m per min. The proportion of *P. capitis* transmission was highly dependent on the specific setting. The tail-to-head direction, slow movement, and a parallel direction all proved favorable for transmission. The highest transfer proportion of *P. capitis* (85%) was observed in the setting where the presented hair was laterally slow moving in a parallel way from tail to head. No transmission at all was observed under an angle of 90 degrees. Hair-to-hair *P. capitis* transmission occurred more frequently when hairs were in particular physical and kinetic relationships. This suggests that head lice are less likely to take advantage of many proposed fomite transmission scenarios and are most likely to rely on head-to-head contact for transmission. ***Key words: head lice/pediculosis/*** **Pediculus capitis*****/transmission. J Invest Dermatol 119:629–631, 2002***

Head lice and humans have evolved together partly due to the fact that head lice depend totally on humans for their existence and do not occur on any other host species. Preserved head lice have been found in the hair of mummies from Egypt buried 5000 y ago.

The life stages include eggs, nymphs, and adults with the adult female being the largest at about 5 mm in length and adult males being about 4 mm in length. The smallest nymph is about 1 mm when it hatches from the egg.

Head lice spend most of their life in the hair, not on the scalp, and come down to the scalp to feed. As feeding usually takes about 15 min or less and they feed about three times a day, head lice really spend only a small amount of their life on the scalp. As most people search for head lice on the scalp, relatively few head lice are found. Many head lice infections cause no symptoms, and probably less than half cause itch, so these symptoms are unreliable as indicators of lice presence. Locating head lice in hair is difficult because they move quickly away from disturbances, climbing rapidly up and down shafts and sideways across to other shafts. For further information on how they climb and how fast they go, see Nuttall's (1917) classic paper on the physiology of *Pediculus humanus*.

Manuscript received September 2001; revised November 2001; accepted for publication June 10, 2002

Reprint requests to: Dr Deon Canyon, School of Public Health & Tropical Medicine, James Cook University, Townsville, QLD 4811, Australia. Email: Deon.Canyon@jcu.edu.au

Eggs are not difficult to see on the hair shafts. Newly laid eggs are usually within 1.5 cm of the scalp, whereas older eggs are higher up the hair shafts. An easy way to find the climbers is to use the conditioner and comb technique described in the Head Lice Information Sheet (Speare, 2001). Typical commercially available head lice products fall into four groups on the basis of active ingredient: pyrethrins, synthetic pyrethroids, malathion, and herbal agents. See the site in Speare, (2001) for more information.

The global increase in pediculosis due to insecticide resistance is well established (Gratz, 1997). Recent findings in Australia have shown that *Pediculus capitis* De Geer, infestations in urban primary schools are at a hyperendemic level with the main source of infestation identified at the classroom level indicating clustering or close contact as the primary cause (Speare and Buettner, 1999). Hard data are thus required on the mechanisms involved in *P. capitis* transmission so that control programs do not squander limited resources (Burkhart and Burkhart, 2000).

This study presents information on the prerequisites for head-to-head transmission in support of the argument that this transmission mode is the primary mechanism by which *P. capitis* spreads through a human population.

MATERIALS AND METHODS

All experiments were conducted with freshly caught *P. capitis* within 24 h after they had been combed from the heads of primary school children in regular school head lice control programs. The standard collection method is to run a fine-toothed plastic comb through hair containing ample conditioner. The collected lice are rinsed off and

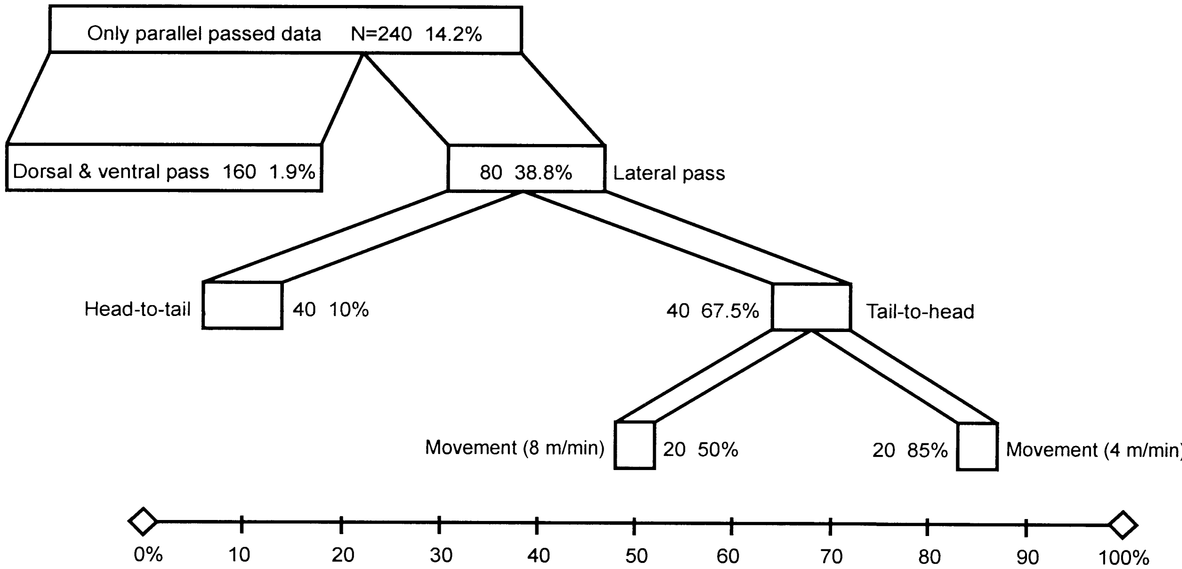

Figure 1. Classification and regression tree (CART) for head lice hair-to-hair transmission data (only data for parallel passing displayed as no lice transferred under perpendicular passing conditions). Box width denotes subgroup size, whereas horizontal positions depict transfer proportions.

Table I. Bivariate findings of transmission proportions under the factorial design (n = 480) (factorial design implies balanced subgroups (e.g., n = 240 *vs* n = 240)

Factor	Transmission proportions	P-value (Chi-square test)
Direction: head-to-tail *vs* tail-to-head	1.7% *vs* 12.5%	$p < 0.0001$
Speed: 4m/min *vs* 8m/min	10.0% *vs* 4.2%	$p = 0.013$
Position: ventral *vs* dorsal *vs* lateral	1.9% *vs* 0% *vs* 19.4%	$p < 0.0001$
Movement: stationary to moving *vs* moving to stationary	7.9% *vs* 6.3%	$p = 0.48$
Angle: 90° *vs* 0°	0% *vs* 14.2%	$p < 0.0001$

blood-fed immediately. Using this method, we have shown that we can recover most if not all the lice on an individual's head (Canyon, unpublished). As the lice used in the study were combed off recently infested individuals, they were all in the adult stage of development. Earlier life stages appear to be less likely to transfer (Canyon, unpublished). No further demographics (age, gender, general health) were collected from the lice, but selection bias is minimal.

The head lice were maintained by being blood-fed at least once on the back of the hand of one of the experimenters to ensure their health before the experiments.

Ten replicates were used in each of the 48 factorial experimental situations. All experiments used 30 cm long single strands of hair collected from a person without pediculosis. The hair type was thick, caucasian brown, and had been recently cleaned. Each hair was tightly suspended between two points and a louse was placed in the middle of the hair. Another fairly straight 10 cm hair strand, hand-held at the base and lightly touching the head louse, was passed either from head-to-tail or from tail-to-head over the dorsal, ventral, and lateral surfaces of the louse so as to simulate a hair from another individual moving past the original hair. The moving hair was passed parallel and at 90° to the stationary hair and was moved at speeds of 4 m and 8 m per min. Contact between passing hairs and the lice was maintained for at least 80% of each pass.

The above scenario was repeated for head lice situated on the moving hair in relation to the vacant stationary hair. All hair passes involved contact between the uninhabited hair and the lice. Head lice movement between hairs was recorded.

Standard chi-square tests were used for bivariate comparisons of transmission proportions. In addition, a CART (Classification and Regression Trees) analysis (Breiman *et al*, 1984) was performed to find the most unfavorable/favorable conditions for transmission. This technique determines the most relevant factor for the outcome (transmission proportion) that is then used to split the overall sample in respective subgroups. This procedure is repeated in the identified subgroups until certain stopping rules bring the splitting process to an end. In the graphical display (**Fig 1**) the splitting process is documented, the respective group sizes are identified by the width of the boxes and the horizontal position of the boxes reflects the transmission rates. For all test procedures, $p < 0.05$ was regarded as significant.

RESULTS

Overall, a transfer proportion of 7.1% (34 of 480) was observed. In all successful transfers, the claw on the first leg was the only claw used to make contact with a new hair and other legs were only used after the first claw was securely attached. No lice (none of 240) were able to transfer to a hair when it passed them at 90°.

The bivariate findings of transfer proportions (n = 480) with respect to the different settings are detailed in **Table I**. Data for parallel hair passes (n = 240; overall transfer proportion 14.2%) were submitted to a CART analysis and the resulting classification tree is presented in **Fig 1**.

This analysis revealed, that for parallel passes, the most significant factor for transfer was the position of the passing hair relative to the louse body. The consecutive splitting procedure points out that lateral passes (*vs* dorsal/ventral), tail-to-head direction (*vs* head-to-tail) and slow speed (4 m per min *vs* 8 m per min) were significantly favorable for transfer proportions. The highest transfer proportion (85%) was achieved in the setting where the presented hair was laterally slow (4 m per min) moving in a parallel orientation from tail to head. Under dorsal and ventral passing, even in a parallel direction, only 1.9% transferred.

DISCUSSION

The relatively low overall transfer proportion of 7.1% in ideal circumstances does not support the assertion by Burkhart and Burkhart (1999) that transmission takes place between individuals "by the slightest bodily contact".

This study has demonstrated that transfer from hair to hair is highly dependent on specific spatial and kinetic patterns. The preference for hairs passing slowly from tail-to-head may be due to anatomical and behavioral factors in the head lice because, in all experiments, the claw on the first leg was the only claw used to make contact with a new hair and other legs were only used after the first claw was securely attached. The safety provided by the current hair may have superseded the opportunity to transfer to a passing hair because five legs often remained on the current hair, whereas the sixth leg was used in a repeated motion grasping for passing hairs. In other experiments (pers. obs.), head lice were observed to transfer only when the grasping claw had locked on to a passing hair and that slipping due to oil inhibited transmission.

The results indicate that for transfer of head lice to take place at an optimum rate, head lice need to be correctly positioned. Head lice oriented for blood meals with their head close to the scalp would not come into contact with passing hairs in the orientation shown to be most advantageous in this study. Head lice that are not searching for a blood meal occasionally position themselves above the host's scalp with their tails facing the host's head. This position would facilitate transmission because a passing hair would most often come into contact with a louse in a parallel and tail-to-head orientation during hair-to-hair contact. The anatomical optimizations of head lice and their transmission abilities are closely linked in that they are clearly designed for hair-to-hair transmission, but only when they orient themselves correctly.

It is believed that fomites (Burkhart and Burkhart, 1999) and head-to-head contact (Speare and Buettner, 2000) play important parts in head lice transmission. The clustering of infestations reported in primary schools (Speare and Buettner, 1999) supports the notion that group behavior with repeated and prolonged head-to-head contact is required for a significant amount of transmission to occur. The low transmission rates we observed may be a reflection of this. The results of this study suggest that a set of specific spatial and kinetic factors are required for optimal transmission of head lice and do not support the hypothesis that head lice are able to transfer from head-to-head by the slightest bodily contact. Further experimental work needs to be done to investigate the requirements for and the dynamics of hair-to-hair transmission on the human host.

We gratefully acknowledge the provision of freshly caught head lice from Ms. Chris Cahill and other helpers of the Head Lice Research Unit in the School of Public Health and Tropical Medicine at James Cook University, Townsville, QLD, Australia.

REFERENCES

Breiman L, Friedman JH, Olshen RA, Stone CJ: *Classification and Regression Trees (CART)*. Belmont, CA: Wadsworth International, 1984

Burkhart CN, Burkhart CG: Odds and ends of head lice: characteristics, risk of fomite transmission, and treatment. *J Clin Dermatol* 2:15–18, 1999

Burkhart CN, Burkhart CG: The route of head lice transmission needs enlightenment for proper epidemiologic evaluations. *Int J Dermatol* 39:878–879, 2000

Gratz NG: *Human Lice. Their Prevalence, Control and Resistance to Insecticides. A Review 1985–1997*. Geneva: World Health Organization, 1997

Nuttall GHF: The biology of *Pediculus humanus*. *Parasitology* 10:80–185, 1917

Speare R: The Head Lice Information Sheet. http://www.jcu.edu.au/school/phtm/PHTM/hlice/hlinfo1.htm. January, 2001

Speare R, Buettner PG: Head lice in pupils of a primary school in Australia and implications for control. *Int J Dermatol* 38:285–290, 1999

Speare R, Buettner PG: Hard data needed on head lice transmission. *Int J Dermatol* 39:877–878, 2000