A pilot study using wearable global position system (GPS) dataloggers to compare water contact levels: *Schistosoma haematobium* infection in pre-school-aged children (PSAC) and their mothers at Barombi Kotto, Cameroon

Grace Macklin[a,+], Michelle C. Stanton[b], Louis Albert Tchuem-Tchuenté[c], J. Russell Stothard[a,*]

[a] Department of Parasitology, Liverpool School of Tropical Medicine, Liverpool, UK; [b] Faculty of Health and Medicine, Lancaster University, Lancaster, UK; [c] Centre for Schistosomiasis & Parasitology, Yaoundé, Cameroon

[+] present address: London School of Hygiene and Tropical Medicine, Keppel Street, London WC1E 7HT, UK;

* Corresponding author: Tel: +44 151 7053724; E-mail: russell.stothard@lstmed.ac.uk

Abstract

Barombi Kotto, Cameroon serves as a reference location for assessing intervention strategies against *Schistosoma haematobium*. As part of a pilot study, the whole community was treated with praziquantel, inclusive of pre-school-aged children (PSAC) and their mothers. One year later egg-patent infections were reassessed and water contact patterns of 12 pairs of PSAC and their mother were measured with global position system (GPS) dataloggers. A substantial reduction in general infection prevalence, from 44.8% to 11.7 %, was observed but certain PSAC and mothers continued to have egg-patent infections. Analysis of GPS data demonstrated similar water contact levels between child and mother groups, although certain individuals were numerical outliers. This study shows the potential of GPS dataloggers to clarify the at-risk status of PSAC and mothers.

Keywords
Urogenital schistosomiasis, i-gotU, paediatric schistosomiasis, female genital schistosomiasis, praziquantel

Introduction

Urogenital schistosomiasis is an important waterborne disease, caused by infection with the blood fluke *Schistosoma haematobium*, and common in many parts of sub-Saharan Africa (1). In Cameroon, for example, there is a national control programme active in the distribution of praziquantel (PZQ) to school-aged children (SAC) (2, 3). However, in the move towards local interruption of schistosome transmission, the programme is developing new tactics of control (4) and has benefited from recent bilateral support from China in snail control and environmental surveillance (5), as well as from UK to expand access of interventions (6).

Overlooked for too long, expanding access of PZQ to pre-school-aged children (PSAC) and their mothers is attracting increasing attention (7, 8). It has been shown elsewhere that these groups can be patently infected (9-12) and alongside SAC, may contribute towards schistosome transmission but their water contact(s) is rarely measured and hence the role of PSAC in sustaining local transmission remains speculative (13, 14). As a pilot investigation of expanded access to praziquantel treatment, in June 2016 Campbell *et al.* undertook a detailed cross-sectional epidemiological and malacological survey at Barombi Kotto, Cameroon (15). Barombi Kotto is well-known crater lake and is of significant international interest as a longstanding focus of urogenital schistosomiasis (16-18). Before treating all community members with PZQ, Campbell *et al.* noted that a quarter of PSAC had egg-patent infections. Furthermore, adult women had raised signs and symptoms of female genital schistosomiasis (FGS), the latter is of growing international concern (13, 19). Environmental water contact is very common across the community, for example, bathing, washing and other domestic chores are typically performed on the immediate shoreline of the island while potable water is collected in plastic containers from a local stream which is only accessible by canoe (15). The level of environmental water contact, however, on the immediate lake shoreline of both PSAC and their mothers remained to be determined and compared.

To shed fresh light on the at-risk status of PSAC and their mothers, using wearable global position system (GPS) dataloggers, we attempted to measure and compare the water contact patterns of PSAC and their mothers (20, 21). Furthermore, we hoped to pinpoint water contact sites, measuring putative immersion times, on the Barombi Kotto crater lake shoreline as baseline information for future interventions.

Methods & Materials

Study location and parasitological examination

This parasitological resurvey and GPS study was conducted in June 2017 in the community on the central island of Barombi Kotto crater lake, where some 375 people are permanent residents. Study protocols were approved by the Liverpool School of Tropical Medicine Research Ethics Committee and the Cameroon National Ethical Committee of Research for Human Health. Participation involved obtaining written informed consent from mothers and their PSAC before deployment of the GPS datalogger. A total of 179 individuals (20 PSAC, 55 SAC and 104 adults) underwent a parasitological reinspection where each provided a 10ml urine sample which was filtered and stained with Lugol's iodine to visualise S. *haematobium* eggs by microscopy as described previously (15). All participants found infected with schistosomiasis were offered and observed to take praziquantel treatment (40 mg/kg)

Water exposure assessment

A subset of 12 mothers and PSAC pairs were randomly selected, then 6 pairs were assigned into two groups to wear the GPS dataloggers (i-gotU-120, Mobile Action, UK; dimension 44.5 x 28.5 x 13 mm, weight 20 g) over a 48-hour period on two occasions. The dataloggers were worn on the arm or wrist using a custom made elastic strap (20). The dataloggers were configured to record GPS location and velocity at 1 minute intervals during waking hours (05:00-21:00). Analysis of GPS data was conducted in QGIS (22) and filtered per the velocity filtering method (23). A zone was developed around the lakeshore of the island, 10m into the lake and 5m into the shore, a conservative assessment of the positional accuracy of the i-gotU-120 dataloggers based on previous observations (24). A water contact event was defined as a GPS location recording within a defined lakeshore geospatial buffer zone around the island circumference: a conservative assessment of the positional accuracy of the i-gotU dataloggers (24). As the GPS loggers recorded location at 1 minute intervals, each water contact event is analogous to 1 minute spent in the geospatial buffer zone and could be tallied and compared between individuals and groups.

Statistical analysis

Statistical analysis was performed using the R statistical software (25). Prevalence of schistosomiasis was calculated with 95% binomial confidence intervals (95% CIs) with correction for samples of n < 30. The track logs of each GPS unit were plotted and overlaid against a base map of Barombi Kotto shoreline to identify travel patterns on and off the island.

Results and Discussion

<please insert table 1 here>

The characteristics of the study population and infection status is shown in Table 1. In June 2017, the overall prevalence of egg-patent infection was 11.7 % (95% CI 7.0 - 17.0) with only 1 infection of heavy intensity encountered albeit in a PSAC. The epidemiological survey undertaken by Campbell *et al.* one year previously observed a much higher egg-patent prevalence of 40.1% (24.6% in PSAC, 51.3% in SAC and 44.9% in adults). The overall reduction across all demographic groups, see Table 1, is most likely due to the community-wide PZQ treatment.

<please insert Figure 1 here>

Twelve PSAC and mother pairs were randomly selected and assigned into two groups of 6 pairs, to wear the GPS dataloggers on two locations. In total, there were 3 individuals with egg-patent infections (2 mothers and 1 PSAC) and their intensities of egg-patent infections against the sampled population is shown in Figure 1A. The water contact levels of the 12 mother and child pairs for the 48 hour period is shown in Figure 1B. This documents a high level of water contact events (reaching up to 166 water contact events in 24 hours) in both mothers and PSAC on the Barombi Kotto shoreline. As data points were recorded at 1 minute intervals, the number of water contact events can be interpreted as the time spent in water contact which would likely positively correlate with actual bodily immersion or skin contact with lake shore water.

The average number of water contact events in 24 hours were 27.4 [95% CIs: -1.3, 56.1] for mothers and 14.1 [95% CIs: 8.5 ,19.7] for PSAC, with no significant difference between the two groups, Figure 1B. These findings have important implications in that water contact levels of PSAC should not to be overlooked and follow similar levels to that observed in Uganda (20). In Uganda PSAC were observed to spend on average half an hour on the shoreline of Lake Albert and were clearly shown to be an at-risk vulnerable group not only to first infection but also re-infection (10), as evidenced here in Barombi Kotto. Our study shows the potential of GPS data logging technology to clarify their at-risk status which should assist in better infection surveillance and control of urogenital schistosomiasis in general as well as for regular access to treatment with the soon to be deployed paediatric PZQ formulation (12).

Upon more detailed inspection of individual water contact patterns, whilst our GPS sample of two infected mothers ("M1", "M2") and one infected PSAC ("X4") was too small to determine a precise relationship between water exposure and infection status, two of these individuals were clear numerical outliers in terms of their water contact(s) (4.6, 166.1, and 31.8 for "M1", "M2" and "X4", respectively). The latter two lying far outside the confidence intervals for PSAC and mother averages. This demonstrates the importance of individual variation in exposure and likely environmental contamination, Figure 1B. Indeed, it is very plausible that the water contact behaviours of "M2" and "X4" could classify them as 'raised-spreaders' who should be specifically targeted for increased frequency of treatment(s) alongside behavioural change interventions. It remains to be seen if these individuals play more pivotal roles than others in facilitating and sustaining local transmission of schistosomes.

Another interesting facet revealed by the GPS dataloggers is the similar geospatial pattern of water contact between the two groups which illustrate that PSAC frequently accompany their mothers to the same locations, Figure C. This is also consistent with other studies using questionnaires (13, 21). Furthermore, observed water contacts were largely co-clustered on the South-West lakeshore of the island, notably an area where activities of the 3 infected cases were concentrated. Micro-spatial heterogeneity of schistosome transmission has been described elsewhere (26, 27) and is further evidenced here, Figure 1D. In the future context of interruption of schistosome transmission (14, 27), as a cost-effective measure, it would be sensible to apply focal molluscicides at this location rather than elsewhere, to have highest impact upon removal of infected snail hosts.

Our findings document that GPS dataloggers are an accepted method of measuring water exposure in PSAC and their mothers and directly compare environmental risk of schistosomiasis exposure. We suggest that in future the water contact levels of these two demographic groups should further investigated. The wearable GPS technology is also of value to identify putative transmission foci for spatial targeting of interventions.

Authors Contributions

JRS and MS conceived the study; GM, MS, LATT and JRS designed the study protocol; GM carried out the field work; GM and MS carried out the analysis and interpretation of these data. GM and JRS drafted the manuscript with LATT and MS critically revising. All authors read and approved the final manuscript.

Funding

GM is in receipt of a Scholarship from the Medical Research Council, United Kingdom. This study was additionally funded as part of the COU**NTD**OWN research programme consortium, by the Research and Evidence Division of the Department for International Development, UK. The funders had no role in study design, decision to publish, or preparation of the manuscript.

Acknowledgments

We are grateful to Drs James LaCourse and Martyn Stewart, LSTM who helped with local fieldwork in Cameroon, as well as, the local community and field team volunteers at Barombi Kotto.

Competing interests

None declared

Ethical approval

The study was approved by the Liverpool School of Tropical Medicine and the Cameroon National Ethical Committee of Research for Human Health.

References

1. Colley DG, Bustinduy AL, Secor WE, et al.; Human schistosomiasis. *Lancet* 2014;**383**(9936):2253-64. doi: 10.1016/S0140-6736(13)61949-2.
2. Tchuente LAT, N'Goran EK; Schistosomiasis and soil-transmitted helminthiasis control in Cameroon and Cote d'Ivoire: implementing control on a limited budget. *Parasitology* 2009;**136**(13):1739-1745. doi: 10.1017/s0031182009005988.
3. Tchuente LAT, Noumedem CD, Ngassam P, et al.; Mapping of schistosomiasis and soil-transmitted helminthiasis in the regions of Littoral, North-West, South and South-West

Cameroon and recommendations for treatment. *Bmc Infectious Diseases* 2013;**13**. doi: 10.1186/1471-2334-13-602.
4. Tchuente LAT, Rollinson D, Stothard JR, et al.; Moving from control to elimination of schistosomiasis in sub-Saharan Africa: time to change and adapt strategies. *Infectious Diseases of Poverty* 2017;**6**. doi: 10.1186/s40249-017-0256-8.
5. Xu J, Yu Q, Tchuente LAT, et al.; Enhancing collaboration between China and African countries for schistosomiasis control. *Lancet Infectious Diseases* 2016;**16**(3):376-383. doi: 10.1016/s1473-3099(15)00360-6.
6. Stothard JR, Kabatereine NB, Archer J, et al.; A centenary of Robert T. Leiper's lasting legacy on schistosomiasis and a COUNTDOWN on control of neglected tropical diseases. *Parasitology* 2017;**144**(12):1602-1612. doi: 10.1017/s0031182016000998.
7. Bustinduy AL, Friedman JF, Kjetland EF, et al.; Expanding Praziquantel (PZQ) Access beyond Mass Drug Administration Programs: Paving a Way Forward for a Pediatric PZQ Formulation for Schistosomiasis. *Plos Neglected Tropical Diseases* 2016;**10**(9). doi: 10.1371/journal.pntd.0004946.
8. Lo NC, Addiss DG, Hotez PJ, et al.; A call to strengthen the global strategy against schistosomiasis and soil-transmitted helminthiasis: the time is now. *Lancet Infectious Diseases* 2017;**17**(2):E64-E69. doi: 10.1016/s1473-3099(16)30535-7.
9. Bustinduy AL, Stothard JR, Friedman JF; Paediatric and maternal schistosomiasis: shifting the paradigms. *British Medical Bulletin* 2017;**123**(1):115-125. doi: 10.1093/bmb/ldx028.
10. Mduluza T, Mutapi F; Putting the treatment of paediatric schistosomiasis into context. *Infectious Diseases of Poverty* 2017;**6**. doi: 10.1186/s40249-017-0300-8.
11. Stothard JR, Sousa-Figueiredo JC, Betson M, et al.; Schistosomiasis in African infants and preschool children: let them now be treated! *Trends in Parasitology* 2013;**29**(4):197-205. doi: 10.1016/j.pt.2013.02.001.
12. Reinhard-Rupp J, Klohe K; Developing a comprehensive response for treatment of children under 6 years of age with schistosomiasis: research and development of a pediatric formulation of praziquantel. *Infectious Diseases of Poverty* 2017;**6**. doi: 10.1186/s40249-017-0336-9.
13. Poole H, Terlouw DJ, Naunje A, et al.; Schistosomiasis in pre-school-age children and their mothers in Chikhwawa district, Malawi with notes on characterization of schistosomes and snails. *Parasites & Vectors* 2014;**7**. doi: 10.1186/1756-3305-7-153.
14. Stothard JR, Campbell SJ, Osei-Atweneboana MY, et al.; Towards interruption of schistosomiasis transmission in sub-Saharan Africa: developing an appropriate environmental surveillance framework to guide and to support 'end game' interventions. *Infectious Diseases of Poverty* 2017;**6**. doi: 10.1186/s40249-016-0215-9.
15. Campbell SJ, Stothard JR, O'Halloran F, et al.; Urogenital schistosomiasis and soiltransmitted helminthiasis (STH) in Cameroon: An epidemiological update at Barombi Mbo and Barombi Kotto crater lakes assessing prospects for intensified control interventions. *Infectious Diseases of Poverty* 2017;**6**. doi: 10.1186/s40249-017-0264-8.
16. Duke BOL, Moore PJ; Use of a molluscicide in conjunction with chemotherapy to control *Schistosoma haematobium* at Barombi Lake Foci in Cameroon. 3. Conclusions and costs. *Tropenmedizin Und Parasitologie* 1976;**27**(4):505-508.
17. Gonsufotsin J, Tagnizukam D, Moyousomo R, et al.; Ultrasonographic study of urological lesions of urinary bilhariasis in children in Barombi Kotto (Cameroon). *Semaine Des Hopitaux* 1990;**66**(13):680-684.

18. Somo RM, Zukam DT, Kouamouo J, et al.; An epidemiological and radiological study of vesical schistosomiasis foci of the Barombi Lakes, Meme Division, Cameroon. *Bulletin De La Societe De Pathologie Exotique* 1987;**80**(5):813-822.
19. Christinet V, Lazdins-Helds JK, Stothard JR, et al.; Female genital schistosomiasis (FGS): from case reports to a call for concerted action against this neglected gynaecological disease. *International Journal for Parasitology* 2016;**46**(7):395-404. doi: 10.1016/j.ijpara.2016.02.006.
20. Seto EYW, Sousa-Figueiredo JC, Betson M, et al.; Patterns of intestinal schistosomiasis among mothers and young children from Lake Albert, Uganda: water contact and social networks inferred from wearable global positioning system dataloggers. *Geospatial Health* 2012;**7**(1):1-13.
21. Stothard JR, Sousa-Figueiredo JC, Betson M, et al.; Investigating the spatial micro-epidemiology of diseases within a point-prevalence sample: a field applicable method for rapid mapping of households using low-cost GPS-dataloggers. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 2011;**105**(9):500-506. doi: 10.1016/j.trstmh.2011.05.007.
22. QGIS Development Team; QGIS Geographic Information System. Open Source Geospatial Foundation, 2009.
23. Seto EYW, Knapp F, Zhong B, et al.; The use of a vest equipped with a global positioning system to assess water-contact patterns associated with schistosomiasis. *Geospatial Health* 2007;**1**(2):233-241. doi: 10.4081/gh.2007.271.
24. Morris G, Conner LM; Assessment of accuracy, fix success rate, and use of estimated horizontal position error (EHPE) to filter inaccurate data collected by a common commercially available GPS logger. *Plos One* 2017;**12**(11). doi: 10.1371/journal.pone.0189020.
25. R Core Team; R: A Language and Enviroment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing, 2016.
26. Levitz S, Standley CJ, Adriko M, et al.; Environmental epidemiology of intestinal schistosomiasis and genetic diversity of Schistosoma mansoni infections in snails at Bugoigo village, Lake Albert. *Acta Tropica* 2013;**128**(2):284-291. doi: 10.1016/j.actatropica.2012.10.003.
27. Rollinson D, Knopp S, Levitz S, et al.; Time to set the agenda for schistosomiasis elimination. *Acta Tropica* 2013;**128**(2):423-440. doi: 10.1016/j.actatropica.2012.04.013.

Figure Legend

Figure 1. **A.** The *S. haematobium* egg count frequency for the 21 individuals found positive at the time of community resurvey; **B.** Plot of water contact events over 24 hour period for mothers (n=12) and PSAC (n=12), the black lines denote average with 95% CIs others for mothers [27.4 (-1.3, 56.1)] and PSAC [14.1 (8.6, 19.7)] since our sample size was < 30 instead of using the formula of 1.96*Standard error, 2.201*standard error (11 degrees of freedom) was used. No significant difference was found between water contact events for mother and children groups (P = 0.34, *paired t-test*) evidencing similar water contact levels; **C.** GPS co-ordinates of individuals over a 48-hour period stratified by *S. haematobium* infection status and age with different colours representing individuals: (i) not infected PSAC (n=11); (ii) infected PSAC (n=1); (iii) uninfected mothers (n=10); and (iv) infected mothers (n=2). The

S. haematobium infected mothers (M1 and M2) and child (X4) from the GPS study are identified in plots A and B.