

**Authors**

Amy Pickering  
Tufts University

Sammy Njenga  
Kenya Medical Research Institute (KEMRI)

Audrie Lin  
University of California, Berkeley

Ben Arnold  
University of California, Berkeley

Christine Stewart  
University of California, Davis

Clair Null  
Mathematica Policy Research

bioRxiv preprint first posted online Nov 9, 2018; doi: <https://doi.org/10.1101/468317>. The copyright holder for this preprint (which was not peer-reviewed) is the author/funder, who has granted bioRxiv a license to display the preprint in perpetuity. All rights reserved. No reuse allowed without permission.

1 Integrating water, sanitation, handwashing, and nutrition interventions to reduce child soil-  
2 transmitted helminth and *Giardia* infections: a cluster-randomized controlled trial in rural  
3 Kenya

4  
5 Amy J. Pickering<sup>1,2\*</sup>, Sammy M. Njenga<sup>3</sup>, Lauren Steinbaum<sup>2</sup>, Jenna Swarthout<sup>1,4</sup>, Audrie Lin<sup>5</sup>,  
6 Benjamin F. Arnold<sup>6</sup>, Christine P. Stewart<sup>7</sup>, Holly N. Dentz<sup>8</sup>, MaryAnne Mureithi<sup>9</sup>, Benard  
7 Chieng<sup>3</sup>, Marlene Wolfe<sup>1,4</sup>, Ryan Mahoney<sup>4</sup>, Jimmy Kihara<sup>3</sup>, Kendra Byrd<sup>3</sup>, Gouthami Rao<sup>4</sup>,  
8 Theodora Meerkerk<sup>9</sup>, Priscah Cheruiyot<sup>3</sup>, Marina Papaloukou<sup>10</sup>, Nils Fjeltbe<sup>11</sup>, Steven A.  
9 Williams<sup>12</sup>, John M. Colford, Jr.<sup>13</sup>, Clair Null<sup>14</sup>

10  
11 1 Civil and Environmental Engineering, Tufts University, Medford, MA, USA, 02155  
12 2 Civil and Environmental Engineering, Stanford University, Stanford, CA, USA, 94305  
13 3 Kenya Medical Research Institute, Nairobi, Kenya, 34567-00100  
14 4 Innovations for Poverty Action, Kakamega, Kenya, 72427-00200  
15 5 Division of Epidemiology, School of Public Health, University of California, Berkeley, CA, USA,  
16 94720  
17 6 Department of Nutrition, University of California, Davis, CA, USA, 95616  
18 7 Smith College, Northampton, MA, USA, 01063  
19 8 Department of Life Sciences, Natural History Museum, London, UK, SW7 5BD  
20 9 Center for International Policy Research and Evaluation, Mathematica Policy Research,  
21 Washington DC, USA, 20002  
22

23 Correspondence to: Amy J. Pickering, Civil and Environmental Engineering, Tufts University, 113  
24 Anderson Hall, 200 College Avenue, Medford, MA 02155, amy.pickering@tufts.edu.

25  
26 Short title: Integrated WASH and child parasite infections  
27 Trial registration: ClinicalTrials.gov NCT01704105,  
28 <https://clinicaltrials.gov/ct2/show/NCT01704105>

# Integrating water, sanitation, handwashing, and nutrition interventions

# to reduce child soil-transmitted helminth and Giardia infections: a cluster-randomized controlled trial in rural Kenya

Background: Helminth and protozoan infections affect >1 billion children globally. Improved water, sanitation, handwashing, and nutrition could be more sustainable control strategies for parasite infections than mass drug administration (MDA), while providing other quality of life benefits. Methods and Findings: We enrolled geographic clusters of pregnant women into a cluster-randomized controlled trial that tested six interventions: disinfecting drinking water(W), improved sanitation(S), handwashing with soap(H), combined WSH, improved nutrition(N), and combined WSHN. We assessed intervention effects on parasite infections by measuring *Ascaris lumbricoides*, *Trichuris trichiura*, hookworm, and *Giardia duodenalis* among individual children born to enrolled mothers and their older siblings (ClinicalTrials.gov NCT01704105). We collected stool specimens from 9077 total children in 622 clusters, including 2346 children in control, 1117 in water, 1160 in sanitation, 1141 in handwashing, 1064 in WSH, 1072 in nutrition, and 1177 in WSHN. In the control group, 23% of children were infected with *Ascaris lumbricoides*, 1% with *Trichuris trichiura*, 2% with hookworm and 39% with *Giardia duodenalis*. After two years of intervention exposure, *Ascaris* infection prevalence was 18% lower in the water treatment arm (95% confidence interval (CI) 0%, 33%), 22% lower in the WSH arm (CI 4%, 37%), and 22% lower in the WSHN arm (CI 4%, 36%) compared to control. Individual sanitation, handwashing, and nutrition did not significantly reduce *Ascaris* infection on their own, and integrating nutrition with WSH did not provide additional benefit. *Trichuris* and hookworm were rarely detected, resulting in imprecise effect estimates. No intervention reduced *Giardia*. Reanalysis of stool samples by quantitative polymerase chain reaction (qPCR) confirmed the reductions in *Ascaris* infections measured by microscopy in the WSH and WSHN groups. Lab technicians and data analysts were blinded to treatment assignment, but participants and sample collectors were not blinded. The trial was funded by the Bill & Melinda Gates Foundation and USAID. Conclusions: Our results suggest integration of improved water quality, sanitation, and handwashing could contribute to sustainable control strategies for *Ascaris* infections, particularly in similar settings with recent or ongoing deworming programs. Water treatment alone was similarly effective to integrated WSH, providing new evidence that drinking water should be given increased attention as a transmission pathway for *Ascaris*. Clinical trial registration ID #NCT01704105.

November 09, 2018