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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
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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.

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