Last updated: May 24, 2021

Epidemiology and Economics of Deworming

Donald AP Bundy[1]*, Suzy J Campbell[2], Goylette F Chami[3], Kevin Croke[4], Linda Schultz[5], Hugo C Turner[6+]

Contents

Introduction 2
The Evolution of Deworming Programmes 2
The importance of scale 3
Developing more efficient programmes 3
Towards a new global policy on deworming 4
Global Evidence of Deworming 5
Coverage achieved to date 5
Looking towards the endpoint 6
Elimination as a public health problem or interruption of transmission? 6
Assessing the Impact: the "Worm Wars" and beyond 8
Reviewing the statistical evidence from meta-analyses 8
Debates over long run results of deworming 8
Reframing the debates over evidence as policy decisions 9
The Economics of Interventions 10
Costs related to deworming programmes 10
Delivery cost benchmarks and drivers 10
Cost of the drugs 11
Cost-effectiveness of deworming 11
Economic benefits of deworming 13
Health System Issues 13
Reliance on external support and donations, and MDA instability 13
MDA does not equate with UHC 14
Rethinking infection mapping strategies 14
Towards patient-led, on-demand treatment 15

[1] London School of Hygiene and Tropical Medicine, London, UK; *Corresponding author: Donald.Bundy@lshtm.ac.uk
[2] SCI Foundation, London, UK
[3] Nuffield Department of Population Health, University of Oxford, Oxford, UK
[4] Harvard T.H. Chan School of Public Health, Boston, MA, USA
[5] World Bank, Washington, DC, USA
[6] Imperial College London, London, UK
[+] Authors are listed in alphabetical order, with equal contributions from each author

Improved health information systems to support UHC 15
Future research is needed for UHC integration 16
Conclusions 16
Figures 19
Tables 22
References 27

Abstract

Global access to deworming is one of the public health success stories of the 21st century, and was the key catalyst for creating the Neglected Tropical Disease (NTD) agenda. Human worm infections appear to have been with us since the domestication of household animals, some 10,500 years ago, and putative treatments are known from the earliest pharmacopoeias, but it has only been in the last 100 years that we have sought a public health solution, and only in the last five years that real success at scale has been achieved. This is a success that depends on donated drugs and targeted treatment campaigns outside of the traditional health system. In this chapter, we explore the scientific foundations for this success and explore what this implies for the future management of soil-transmitted helminths (STH) by health systems. This chapter describes the evolution of public health approaches to reduce the prevalence and morbidity of STH, the evidence of impact of mass drug administration on their target populations, and provides context for the debate that has surrounded these results. This chapter also details the costs of delivering these interventions as well as how future delivery approaches can align with Universal Health Care objectives.

Introduction

Global access to deworming is one of the public health success stories of the 21st century, and was the key catalyst for creating the Neglected Tropical Disease (NTD) agenda. Human worm infections appear to have been with us since the domestication of household animals, some 10,500 years ago, and putative treatments are known from the earliest pharmacopoeias, but it has only been in the last 100 years that we have sought a public health solution, and only in the last five years that real success at scale has been achieved. This is a success that depends on donated drugs and targeted treatment campaigns outside of the traditional health system. In this chapter, we explore the scientific foundations for this success and explore what this implies for the future management of soil-transmitted helminths (STH) by health systems.

The Evolution of Deworming Programmes

Figure 1.2 tracks the evolution of deworming programmes from their start as large scale projects before the 1970s to the global movement and national programmes that are the norm today.

The earliest public health programmes that would be recognizable to us today as community deworming were the Rockefeller Hookworm campaigns of the early 20th century, in the southern USA and certain endemic countries (Ettling 1981; Stiles and Garrison 1906). Despite the toxicity and low efficacy of the

drugs then available, recent re-analysis shows that these programmes may have been successful in supporting human development (see Bleakley 2007 for apparently positively outcomes, and Roodman 2018 for a critical analysis), and they laid the conceptual foundation for much of what was to follow.

In tracking this process there are three inter-related strands that developed together. Two of these strands were science-driven: one was the accumulation of evidence of the scale of health impact and the other the development of cost-efficient interventions, based on growing understanding of epidemiology, pharmaceuticals, and public health implementation science. The third strand depended upon the success of these two, and was the slow and difficult evolution in public health policy.

The importance of scale

The scale of infection had long been recognized, but it took the global chaos of human movements during the second world war to remind the public health community that worms were the most ubiquitous of chronic human infections, as memorably reported in "This Wormy World" (Stoll 1947). The ground-breaking work of Julia Walsh and Kenneth Warren (Walsh and Warren 1979) led to growing recognition that these 100s of millions of STH infections could add up to a huge public health burden even if each individual case was not a clinical priority. In the 1980s the Rockefeller Foundation launched the Great Neglected Diseases programme and cited *Ascaris lumbricoides* infection as an exemplar of this principle (Warren et al. 1994). In 1993 the World Bank's World Development Report "Investing in Health" (World Bank 1993), explored the economic argument for investing in diseases based on their scale, impact and cost, and presented the use of DALYs (Disability Adjusted Life Years) as a way of quantifying the impacts of disease beyond their immediate clinical consequences. Soil-transmitted helminths were cited as a specific example where the long term developmental impacts, such as on life-time educational achievement and future earnings, were potentially a greater contribution to the disease burden than short-term clinical disease (Warren et al. 1993).

Developing more efficient programmes

When it became clear that worms were a public health problem, there was greater incentive to find solutions. In the 1970s, several drugs developed originally for veterinary use were licensed for use in humans; worryingly, these remain the most commonly used treatments today. Almost at the same time, parasite epidemiology took an extraordinary leap forward by applying the principles of population dynamics, originally developed for whole organism ecology, to parasite populations (Anderson and May 1982). This showed that STH infections were regulated by the numbers of adult worms present, and thus that reducing infection intensity would simultaneously reduce both morbidity and transmission (see Chapter XX by Gabrielli (2022) in this volume for more details of the biology and epidemiology of STH). Since infection intensity was often age-related (Fig. 1.1), then treating the most heavily infected age-groups of the population should then disproportionately reduce infection and disease in the population as a whole. Applying this theory to practical programme design showed that targeting of treatment at school-age children, who had the most intense infections, resulted in reduced infection in untreated adults (Bundy 1990), and later led to recognition of the economic corollary that there were essentially free additional benefits, or "externalities", to be gained from well-targeted interventions (Miguel and Kremer 2004). In parallel with the focus on targeting there was a surge of implementation science that focused on minimizing treatment delivery costs. Since the cost of individual diagnosis was some 10 times the cost of treatment, the policy game-changer was the acceptance that once a community had been recognized as requiring treatment

this could be rolled-out as mass drug administration (MDA) without further individual screening (Bundy 1990).

[Insert **Fig. 1.1** Cross-sectional surveys of the mean intensity of infection in different age groupings for *Ascaris lumbricoides* (A), *Trichuris trichiura* (B), and hookworm (C) based on worm expulsion studies]

Towards a new global policy on deworming

Global policy change tracked this convergence between recognizing the problem and finding a cost-effective solution. Interest in controlling helminth infections surged after the decision by Merck in 1987 to donate the newly discovered veterinary drug ivermectin for use in controlling river blindness, and pledging "as much as necessary for as long as necessary" (Sturchio 2001). This set a precedent for other major donations: from GlaxoSmithKline in 1997 (2012 for STH), Johnson & Johnson in 2006 and Merck KgaA in 2007 (Table 1.1). The value of school-based MDA was recognized by the education community as part of the FRESH (Focusing Resources on Effective School Health) framework launched at the World Education Forum in Dakar, 2000 (Bundy et al. 2006), which was followed a year later by a World Health Organization (WHO) declaration in support of school-based MDA (WHA 2011).

At the beginning of the 2000s, the epidemiology, economics and policy components were in place for the roll-out of mass treatment programmes to control STH, lymphatic filariasis and onchocerciasis, providing a model approach to addressing some of the most common infections of low-resourced communities. Activists looked back to the analogous *Great Neglected Diseases* programme launched more than 20 years previously, and adopted the new "brand" of *Neglected Tropical Diseases* (WHO 2004; 2006b; Molyneux, Hotez, and Fenwick 2005; Hotez et al. 2006). A new NTD department was opened at WHO in 2005.

[Insert **Table 1.1** Medicines donated by pharmaceutical companies to the World Health Organization for the control of preventive chemotherapy NTDs (PC-NTDs)]

In 2012, a coalition of development partners made a global call, "The London Declaration", to support the WHO NTD 2012-2020 Road Map (WHO 2012), and to continue and expand access to drug donations. Among other pledges, 13 pharmaceutical companies collectively committed to donate 14 billion treatments to control and eliminate ten NTDs, including the five preventive chemotherapy (PC-)NTDS, over a 10 year period (Table 1.1) (Uniting to Combat NTDs 2012). This $18 billion pharmaceutical donation circumvented the scarcity of domestic resources to secure sufficient quality-assured drugs to achieve NTD targets. The London Declaration attracted additional investors and stakeholders to strengthen country capacity to deliver drugs at scale (Espinal et al. 2021). By 2016, more than a billion treatments were being delivered every year, the majority by school-based MDA for STH (Uniting to Combat NTDs 2016), and in the following year, the Guinness World Records recognized the largest drug donation in a single day, with 200 million doses arriving to distribution facilities across six countries (Guinness World Records 2017). In 2021, a second NTD Road Map was launched, charting a path to 2030 (WHO 2020b).

To summarize, Figure 1.2 shows that it took a combination of new approaches to launch the ultimately successful movement towards making deworming universally accessible. The first 30 years (1970 to 2000) were largely focused on demonstrating the previously unrecognized development burden, and to creating a control approach, based on the "new" safer anthelmintics, which was also good value for money because it was focused only on a subsection of the population, did not require individual diagnosis, was delivered through the existing education system and subsidized by donated treatment. 2000 was the water-shed moment when there was formal normative acceptance by both the education and health sectors. It then took

another 10 years to reach the status of a global movement (perhaps delayed by the "worm wars"?, see below), and it is only in the last 5 years that national programmes at scale have become the new normal. The next section considers how these policy changes were rolled out in practice by countries and development partners.

[Insert Fig. 1.2 Timeline of milestones related to the epidemiological understanding of helminth infections, relevant policy measures, and pharmaceutical donations]

Global Evidence of Deworming

School-age children are the cohort with the highest infection burden for STH, and WHO set a global target of 75% treatment coverage of school-age children (WHO 2012). Focusing treatment on this cohort is anticipated to reduce the greatest burden of attributable morbidity while also holding potential anthelmintic resistance in check (Campbell et al. 2018). Utilizing the existing school infrastructure to deliver periodic MDA for STH and SCH is efficient and cost-effective as it reaches 575 million school-age children in low-income countries (Bundy 2011) and serves a population that has little contact with the formal health system (Bundy et al. 2017). Moreover, treatment with anthelmintics offers educational and nutritional benefits precisely at the time when children are physically and cognitively maturing (Miguel and Kremer 2004; Baird et al. 2016). Moderate- to heavy-intensity (MHII) STH infections are associated with malnutrition, lethargy, stunting and impaired physical and cognitive growth (Crompton and Whitehead 1993; Hall et al. 2008; Stoltzfus et al. 1997).

Coverage achieved to date

Since 2010, some 3.3 billion treatments have been delivered through schools for the control of STH infection (Montresor et al. 2020). There is some indication that the number of school-age children living with STH infections was reduced by half between 2010 and 2015 (Bundy et al. 2018), however the relative contributions of large-scale sustained deworming, improvements to mapping estimates and disease predictions, and socioeconomic development are not possible to elucidate. As of 2018, treatment coverage for STH exceeded 60 percent of school-age children in endemic countries, with 28 (of 96) endemic countries reaching effective treatment coverage for five or more years (≥75%) (Montresor et al. 2020). Of the 28 countries, Burkina Faso and Mali have since stopped MDA and are conducting regular surveillance to detect disease resurgence (Montresor et al. 2020).

Following the London Declaration, most countries scaled up deworming programmes. Many conducted prevalence surveys to determine programmatic area/s, endemicity level, and develop a treatment strategy per WHO recommendations (WHO 2011). This baseline becomes useful for measuring resultant programmatic effectiveness. Although deworming drugs are coordinated by WHO free-of-charge to countries, extensive within-country distribution is required, necessitating budget and personnel commitments. Most countries use national to local "cascade" distribution; the "reverse cascade" is advantageous for monitoring and evaluation (M&E), to effectively transmit local numbers treated to national levels.

Performance tracking is essential; thus, effective M&E is integral. Existing M&E guidance (WHO 2011), geared towards scaling up, prioritises process and performance monitoring, including independent MDA

monitoring and coverage evaluation surveys (WHO 2016) of participants' receipt of deworming tablets. Results guide programmatic improvements, ideally before the next MDA. Whilst country programmes tend to plan monitoring processes, few establish performance evaluation at inception to determine, via reassessment, programmatic effectiveness in reducing disease severity after achieving five rounds of sustained, high-coverage MDA (WHO 2011). Reassessments are critically important for revising treatment frequency in accordance with WHO decision trees (WHO 2011), and, eventually, to determine whether elimination as a public health problem (EPHP) (WHO 2020b) has been achieved. Yet, these surveys are expensive, technically complex (requiring epidemiological oversight), and rarely done without external assistance.

Looking towards the endpoint

Some programmes provide outstanding examples of success. Kenya's National School Based Deworming Programme was established with extensive M&E, including pre- and post-MDA surveys and reassessment surveys, enabling assessment of yearly treatment impact and overall reductions in prevalence and intensity of infection (Mwandawiro et al. 2019). India's National Deworming Day, reaching over 226 million children (WHO n.d.), is the world's largest single-day public health campaign. With substantial government investment and political commitment, India is the exemplar of domestic contribution to deworming. Reassessments have enabled India to conceptualise a five-year Roadmap, further optimising domestic deworming investment.

Preventive chemotherapy's oft-discussed limitation is its inability to prevent reinfection. However, it was never meant to. Preventive chemotherapy for STH was intended as sustained, regular drug provision, for the goal of controlling morbidity from MHII STH infection (WHO and WHO Expert Committee on the Control of Schistosomiasis 2002). It was always recommended to be accompanied by water, sanitation and hygiene (WASH) and health education (WHA 2011) although these often receive inadequate NTD programme attention (Campbell et al. 2016). Long-term, community-wide sanitation infrastructure and hygiene behaviours are believed necessary to sustain disease reductions in endemic settings (Anderson, Truscott, and Hollingsworth 2014; Campbell et al. 2014).

There may also be important lessons to learn from countries that were among the first and most successful in achieving control. Japan and South Korea both made a very intentional effort to eliminate STH infections. They both used school-based selective drug administration, combined with: regular mass screening, health education, night soil treatment, improved WASH infrastructure, and specific legislation, such as the Parasitosis Prevention Law in Japan (Hasegawa et al. 2020; Hong et al. 2006). In both cases the decline in infection was accompanied by economic development and socioeconomic improvements. This is also true for Kenya and India, and can only help reinforce the sustainability of the interventions. The economic trajectory of most countries where STH are present today is also upwards, and the World Bank estimates that a third of low-income countries in Africa will be middle income countries by 2030.

Elimination as a public health problem or interruption of transmission?

Since 2012, public health policy has gradually shifted from morbidity control, to EPHP, and more recently, some programmes express plans to achieve "interruption of transmission" (IOT). In 2030 targets, EPHP is defined as achieving <2% proportion of MHII STH infections (WHO 2020b). While this may represent achievement of IOT, this is as yet unproven; however, analyses suggest attainment is not uniformly possible

(Brooker et al 2015). If EPHP attainment becomes used to then stop preventive chemotherapy, there will need to be more direct evidence and consideration of other control aspects; otherwise, analyses indicate resurgence of STH if solely preventive chemotherapy to SAC is provided. Countries must be enabled for success; yet currently, major evidence shortfalls for IOT include metrics, diagnostic techniques, resources, country capacity, survey methodologies, and validation criteria. Interruption of transmission will likely require increased domestic and donor funding, intensified mapping (including methodologies and diagnostics), increased treatments to more cohorts, community-based augmentation of school-based platforms, WASH, lower-administrative implementation units, analyses of undifferentiated infections, increased monitoring, tracking of MDA compliance, and monitoring of anthelmintic resistance. Current donations and resourcing do not extend to this. Pharmaceutical companies aim to reduce drug donations, and focus on eliminating lymphatic filariasis, onchocerciasis and trachoma (considered possible by preventive chemotherapy). Unless evidence-based, implementable prospects for IOT are forthcoming, there may be reduced donor interest in maintaining long-term STH preventive chemotherapy.

Ground-breaking trials include the WASH Benefits randomised controlled trials (RCTs) of WASH and nutrition interventions on outcomes including STH in Kenya and Bangladesh (Luby et al. 2018; Null et al. 2018), the TUMIKIA RCT of community-wide versus school-based treatment in Kenya (Pullan et al. 2019), and, the multi-country Deworm3 RCT which will provide evidence toward feasibility of IOT using biannual MDA to all ages (Ásbjörnsdóttir et al. 2018). A programmatic effort to achieve IOT, using tailored strategies, is the Deworming Innovation Fund, aiming to achieve national IOT in Rwanda and Zimbabwe, county IOT in Kenya, and acceleration towards national IOT in Ethiopia (The END Fund 2020; CIFF 2020).

Looking forward, attention should shift to programmatic and technical requirements of country deworming programmes now that they are scaled up. There are now few STH endemic landscapes without a control programme (some exceptions include conflict zones). Many countries have reached a “tipping point” of successive years of MDA; every country can anticipate needing at least one, and the majority, two, reassessments before 2030. Crucially, robust guidance is needed regarding what countries do when they achieve EPHP; the basis of the 2030 targets (WHO 2020b). At that point, countries are at a decision-making nexus, with scarce evidence for every scenario. They can (i) reduce treatment frequency (per WHO decision trees; (WHO 2011)), (ii) retain treatment frequency, or (iii) intensify activities (increasing treatment frequency and/or incorporating other activities, possibly towards IOT) (Fig. 1.2). Programmatic, technical, sustainability, and resource-based parameters for each decision vary dramatically. Thus, the need for evidence-informed, global M&E frameworks for STH has become acute.

[Insert **Fig. 1.3** The need for an evidence-informed monitoring and evaluation framework]

With increased focus on self-reliance and domestic financing towards 2030, the WHO supplemental Sustainability Framework for Action (WHO 2021) aims to guide governments on embedding NTD programmes within national health strategies. In this context, it is worth noting that the India National Deworming Day programme is almost entirely supported from domestic funds and domestically produced anthelmintics. If the largest deworming programme in the world can be self-reliant then there is hope for programmes everywhere.

In the next section we consider the evidence that these programmes have had an impact on their target populations, and discuss the debate that has surrounded these results.

Assessing the Impact: the "Worm Wars" and beyond

The previous sections have described the long trajectory of deworming programmes, and the growing global progress in scaling up these programmes, lowering STH burdens, and reducing associated morbidity. However, despite this progress, there has been some disagreement about the evidence base for health gains at population level from MDA for deworming. This section discusses these debates.

Reviewing the statistical evidence from meta-analyses

Perhaps the most important disagreement relates to how to aggregate and interpret over 40 years of randomized trials of MDA. Many individual MDA trials have been underpowered to detect meaningful changes in health and nutrition outcomes, so meta-analytic approaches are important tools. Nonetheless, implementation of meta-analysis and interpretation of findings on this topic remains contested. A series of Cochrane systematic reviews and meta-analyses, mostly recently in 2015 (Taylor-Robinson et al. 2015) and in 2019 (Taylor-Robinson et al. 2019), and a Campbell Collaboration review (Welch et al. 2016) found no average impact of MDA for deworming on nutritional and educational outcomes. By contrast, other meta-analyses have aggregated a larger set of studies and found significant effects, most notably for weight gain, which is the nutritional outcome most commonly measured in STH trials (Croke et al. 2017).

Early versions of these systematic reviews differed significantly in their point estimates of average effects of MDA (Taylor-Robinson et al. 2015; Croke et al. 2017). However, over time, and with scientific exchanges between the review teams, the reviews have begun to converge in the population of included studies, and accordingly in the point estimates for key outcomes. For example, the most recent Cochrane review (Taylor-Robinson et al. 2019) estimates an average effect of MDA on weight of 0.11 kg (95% confidence interval (CI) -0.01, 0.24) while the Croke et al. (2017) review estimates an effect of 0.13 kg (95% CI 0.03, 0.24). Notably, these meta-analyses also agree in their finding that trials which dewormed children with confirmed worm infections produced large benefits. Taylor-Robinson et al. (2019) do not separately analyze "test and treat" studies but the 2015 Cochrane Review (Welch et al. 2016) found significant gains in nutritional outcomes (e.g. weight, height, middle-upper arm circumference) from these studies.

Indeed, while the various systematic reviews continue to differ in inclusion/exclusion and data extraction decisions regarding individual studies, the convergence of point estimates, and the agreement that deworming treatment brings nutritional benefits to infected populations, suggests that the most pressing question about MDA relates to the cost-effectiveness and the spatial and temporal targeting of the intervention.

Debates over long run results of deworming

Separately from debates over the short run health effects of MDA, a separate literature focuses on long term benefits to health and broader socioeconomic outcomes. Outside of deworming, a growing literature has demonstrated the importance of early life health and nutrition to adult health and well-being. Thus, an important element of the potential cost-benefit ratio of deworming in childhood is consideration of benefits

over the life course. As with MDA meta-analyses, debates have also emerged over the interpretation of the evidence on this topic. These debates have focused on several influential studies which examine short and long run socioeconomic benefits of deworming, notably the Miguel and Kremer (2004) study of school-based deworming in western Kenya, and findings from longitudinal tracking of this original trial population (Baird et al. 2016; Hicks et al. 2021). In a setting where STH infection was almost universal, Miguel and Kremer (2004) found that mass deworming increased attendance at dewormed schools as well as for those living in close proximity. A re-analysis of this study found an error which reduced estimates of the geographic distance over which beneficial effects of deworming were detected (Aiken et al. 2015). However, subsequent studies have compared the more intensively and less intensively treated cohorts over the longer term, focusing on education, health, and economic outcomes. Baird et al. (2016) found that a decade after treatment, dewormed men worked 17% more hours per week and had higher living standards, while women were more likely to have passed primary-school leaving exams and attended secondary school (Baird et al. 2016). Following the same cohorts after 20 years, Hicks et al. (2021) found that the more intensively treated groups had per capita household consumption expenditure that was 14% higher ($p=0.06$) than less treated groups (Hicks et al. 2021). This leads the authors to estimate 37% annual social internal rate of return for MDA in this setting. Detailed scrutiny of the longitudinal studies (Roodman 2016; 2017) has largely supported the validity of these findings.

However, even as these studies from the Western Kenya cohort demonstrate large benefits over the life course, other recent trials in lower prevalence settings have not found educational or cognitive gains to MDA. For example, Liu et al. (2017) do not find any nutritional or test scores gains from MDA in schools in rural China, while Croke and Atun (2019) do not find significant literacy or numeracy gains 10 years after early childhood deworming in rural eastern Uganda, although effects on nutrition had been observed soon after treatment. As with studies of short-run health outcomes, heterogeneous effects are likely mediated by environmental conditions; both the China and Eastern Uganda settings were low to medium prevalence and light intensity settings whereas, as Hicks et al. (2021) note, the high prevalence and heavy intensity of infection around Lake Victoria circa 1998 could explain the large gains that deworming has generated over the life course in that part of Kenya.

Reframing the debates over evidence as policy decisions

How, then, should this complex body of evidence be interpreted by policymakers? We can reframe the debates over statistical evidence in form of a policy decision problem: how should a policy maker with a given level of helminth prevalence think about deworming policies, taking into account expected value, cost, and equity? Decisions about whether or not to support MDA in a given setting requires both synthesis and interpretation of the global evidence base, but also local knowledge and a decision theory perspective. Some analysts have focused on a "hypothesis testing" approach (i.e. whether or not MDA has a zero-average effect across all settings) to inform a binary decision about whether MDA programmes are justified on a global level. However, this approach to evidence synthesis does not match the decision problem facing health policymakers. Perhaps a more relevant policy question in the case of deworming MDA is rather where MDA can be expected to be cost-effective relative to other health interventions in a given setting.

As mentioned above, there is a consensus clinically and in the meta-analyses that infected children should be treated. All recent meta-analyses find that there is large heterogeneity in impact, with significant effects in some trials and settings and minimal effects in others (consistent with the clinical understanding of STH infection). Since treatment of infected children is uncontroversial, it seems likely to be uncontroversial to

presumptively treat high prevalence populations (i.e. where average infection rates are 80-100%). Conversely it is also likely consensus that it does not make sense to conduct MDA in populations with low prevalence and very few to no highly infected children. The policy question globally is where to place the threshold: WHO guidelines place the threshold for annual deworming at 20% prevalence (WHO 2017), and a recent modelling study (Lo et al. 2016) supported this 20% threshold.

A decision theory approach faced by a specific policymaker should integrate global evidence with knowledge of local conditions to generate an expectation of benefit, net of costs, that MDA is likely to generate. A reasonable interpretation of the global evidence base is that deworming has population-level impact on children's nutrition, but that the impacts are likely concentrated in heavily infected individuals, so population benefits (and the statistical power of trials to detect them) will vary by population infection prevalence and especially intensity. There is also some probability, in high prevalence settings, that MDA can benefit individuals over the life course. Equity considerations are also relevant since infection is correlated with poverty and disadvantage. Expected benefits in a given epidemiological context should therefore consider both short and long run benefits in a probabilistic framework, and should be compared to the modest costs of MDA, and the cost/benefit profile of other health interventions.

The quality of data and analysis of the impact of deworming programmes has improved with time, and current evidence suggests that, in some settings, the impacts are substantial and long term. In the next section we consider the costs of achieving these impacts.

The Economics of Interventions

One of the first key areas of health economics analysis related to deworming was whether selective treatment should be used i.e., where only those that are tested positive for infection (or suspected to be infected) are treated or mass treatment. Although selective treatment uses fewer drugs relative to mass treatment, due to the costs associated with conducting the testing and the test's sensitivity, mass treatment is less costly and more effective strategy for deworming (Warren et al. 1993). Consequently, mass treatment became the standard strategy.

Costs related to deworming programmes

The cost of deworming varies between different settings depending on several factors, such as the implementation method, the salaries of healthcare personnel, and the size of the targeted population (Goldman et al. 2007; Gedge et al. 2018; Turner et al., n.d.).

Delivery cost benchmarks and drivers

Current benchmarks of the delivery costs of mass deworming are generally quoted to be around US$0.50 per treatment (Turner et al., n.d.; Fitzpatrick et al. 2016). However, delivery costs vary across different settings, and are positively correlated with local GDP (Fitzpatrick et al. 2016). Therefore, there are settings with higher delivery costs. Importantly, deworming delivery costs show economies of scale and therefore as the number of people treated increases, the cost per treatment tends to decrease (Turner et al. 2018; Conteh, Engels, and Molyneux 2010). The costs of deworming will therefore depend on the size of the targeted population, and the cost per treatment can be much higher for small programmes.

When comparing different cost estimates it is important to note if these are financial or economic costs. Financial costs represent the actual monetary expenditure for the goods, resources and services that are purchased (i.e., the amount of money paid) for an intervention. Economic costs conceptualize costs more broadly, and represent the full value of the resources utilized in providing an intervention, including the economic value of donated resources (such as unpaid time of health personnel). Economic costs of deworming programmes are therefore typically higher than financial costs.

The precise relative cost of different deworming implementation methods (such as school-based vs community-wide treatment) is currently unknown. It is important to note that even if community-wide treatment has a lower cost per treatment compared to school-based strategies, the total annual cost of community-wide treatment will typically be higher because more individuals are targeted (case study in Table 1.2) (Turner and Bundy 2020). That said, it has been shown that leveraging existing delivery platforms (such as child health days or antenatal clinics) is cheaper than providing the treatment through a dedicated deworming programme (Turner et al., n.d.; Bangert et al. 2019; Chami and Bundy 2019). For example, Boselli et al. (2011) estimated that the delivery costs of adding deworming into an existing immunisation and vitamin A supplementation campaign costs less than US$0.01 per treatment (2009 prices) when targeting children 1-5 years of age and women of childbearing age.

[Insert **Table 1.2** Hypothetical case study of the estimated financial costs of using different treatment strategies within the Kenyan national STH control programme]

Cost of the drugs

The drugs used for deworming are often donated and when this is the case they are not a financial cost to the programmes (Turner et al., n.d.). Their economic value can, however, be included as an economic cost, depending on the study's perspective (viewpoint from which the intervention's costs and consequences are evaluated). The value of donated medicines can be a notable economic cost to deworming programmes (Turner et al., n.d.). GlaxoSmithKline valuation of donated albendazole is US$0.045 per tablet (which was reduced from a valuation of US$0.19 per tablet in 2009 (Goldman et al. 2011). It should be noted that it is difficult to estimate the true economic cost of these deworming drugs (Turner, Walker, et al. 2019; Turner et al. 2017; Hernando, Colwell, and Wright 2016). In some cases, the value of the drugs reported by donating companies can be higher than the cost of generic versions, and the correct value to use is debatable (Turner et al., n.d.; Hernando, Colwell, and Wright 2016). The market price of albendazole and mebendazole can be as low as US$0.02-0.03 per tablet, and as high as several hundred dollars within US markets (Pullan et al. 2019; Boselli et al. 2011; Shahriar and Alpern 2020). If and how the donated drugs are valued causes variation in cost-effectiveness estimates of deworming. In addition, some countries do not use donated drugs and purchase their own drugs. Such variation needs to be considered when comparing costing and cost-effectiveness analyses (Turner et al., n.d.).

Cost-effectiveness of deworming

A number of cost-effectiveness analyses have been performed on STH deworming (reviewed in more detail in the Turner et al. (n.d.) paper). The estimated cost-effectiveness of annual school-based deworming for STH has been found to be favourable but varies across different studies (with the cost per DALY averted varying between US$8-1,077 (Table 1.3). This variation is at least partly due to two key factors. The first is the local pre-control endemicity: the higher the endemicity, the higher the level of morbidity. Therefore, as the pre-control endemicity increases so does the cost-effectiveness of deworming. The second factor is

the methods used to estimate the DALYs and how these are changed over time (Turner et al., n.d.). For example, cognitive impairment was removed as a quantifiable sequela of STH infection for Global Burden of Disease Study 2010. Although this was justified by a perceived lack of evidence of causation (Taylor-Robinson et al. 2012), it is an area of debate within the field (Owada et al. 2017; D. A. P. Bundy et al. 2009; Campbell et al. 2016) .

[Insert **Table 1.3** The cost per disability-adjusted life year (DALY) averted estimates relating to annual school-based deworming for STH]

The generalisability of the reported cost-effectiveness estimates of deworming depends on multiple factors, including the epidemiological setting and drivers that influence the delivery costs (Turner et al., n.d.). It is important to consider these when comparing and interpreting different studies for informing policy decisions (Turner et al., n.d.). The majority of the estimates are below the cost-effectiveness thresholds commonly used for low-income countries (Turner et al., n.d.) and the highest estimate relates to a low endemicity setting (20% prevalence, below which mass treatment is not recommended (Table 1.3). A further consideration is that the cost-effectiveness of deworming is greater when considering integrated control, such as the cost-effectiveness of deworming against both schistosomiasis and STH in one programme, as opposed to separate control programmes (Table 1.3).

It is important to note that it is debatable whether the DALYs averted metric (which focus on losses of optimum health) is truly capturing all the long-term benefits and value for money of deworming against STH (Turner et al., n.d.). Consequently, the broad benefits of deworming against STH may not be fully captured by the conventional approaches to cost-effectiveness analysis. For example, Hicks et al. (2021) recently demonstrated significant long-term economic benefits of deworming children, such as on

Box 1: School-based vs community-wide deworming for STH

A key research gap is the relative benefits and cost-effectiveness of switching from school-based to community-wide MDA for STH. On the plus side, using community-wide MDA for STH could reduce infection overall (by treating currently untreated adults and perhaps children not reached through the school-based programme) generating additional health benefits, and in addition, mathematical models suggest that community-wide MDA may contribute to the interruption of transmission (Anderson, Truscott, and Hollingsworth 2014; Truscott et al. 2014; Truscott et al. 2016), which could potentially be cost-saving in the long term (Turner, Truscott, Bettis, et al. 2015). On the minus side, however, community MDA would very significantly increase the number of treatments required, potentially more than doubling costs in the example here (Table 1.2).

The potential benefits of switching to community-wide MDA are highly dependent on the local setting (Anderson et al. 2015). This is illustrated in Fig. 1.1, which shows the different age profiles of infection for the different STH species. Based on these age profiles, the benefits could be notable for hookworm but small for the other species (Truscott et al. 2016; Anderson et al. 2015; Turner, Truscott, Bettis, et al. 2015). The benefits will also be smaller in settings that have a low baseline level of endemicity and for settings that have had past community-wide MDA for lymphatic filariasis. Consequently, the health gains from switching will vary depending on which STH species are endemic, the treatment history and the baseline level of endemicity (Turner and Bundy 2020; Turner, Truscott, Bettis, et al. 2015).

household income. Additionally, the DALY framework fails to acknowledge the implications of socioeconomic context; the burden of disease will vary within at-risk groups based on poverty-related factors.

Economic benefits of deworming

In addition to their impact as measured by averting DALYs, NTDs are known to cause financial hardship among affected individuals, which can exacerbate the cycle of poverty (Fitzpatrick et al. 2017). Therefore, deworming can also have important socioeconomic benefits (as discussed in the Global Evidence of Deworming section) and summarised by Ahuja et al. (2017).

Some studies have estimated the monetary value of the benefits of deworming programmes (Turner, Truscott, Hollingsworth, et al. 2015; Turner et al. 2020). For example, Redekop et al. (2017) estimated large economic benefits from preventive chemotherapy. With these types of studies that the majority of monetised economic benefits are due to the estimated monetary value of productivity gains, and are highly dependent on several assumptions, such as the number of disease cases averted due to deworming, the effect of clinical disease on productivity, the number of years of productive life lived with clinical disease, employment rates and wage rates (Turner 2021). Furthermore, most of the studies use the human capital approach where the loss is that potential production not now performed by a person because of morbidity or early mortality (Gedge et al. 2018; Turner 2021; Turner et al. 2016). Consequently, the estimated monetised economic benefits being quoted in many studies are generally based on potential rather than experienced productivity gains. That said, the overall conclusion that the deworming programmes generate notable economic benefits appears robust and some studies have looked at the actual economic benefits experienced by treated populations.

The evidence suggests that deworming has achieved impact at remarkably low cost. But the programmes are often standalone efforts reliant to a large extent on external funding. Is the success sustainable with the present model? In the next section we envisage future approaches that are more aligned to the aspirations of access to Universal Health Care (UHC).

Health System Issues

Mass drug administration depends on the large-scale donation of medicines, which cannot go on indefinitely if there is donor fatigue, changes in industry leadership, fluctuations in international aid commitments, and global insecurity (Glenn et al. 2020). In this section, we rethink the current approach to deworming, with less emphasis on MDA and school children, and more emphasis on adults and UHC.

Reliance on external support and donations, and MDA instability

A pressing example of the potential vulnerability of MDA to external shocks was shown by the aid cuts which took place when the United Kingdom's Department for International Development (DFID) was merged with the Foreign Commonwealth Office to form the Foreign, Development, and Commonwealth Office, as of 2nd September 2020. By January 2021, UK overseas development assistance for low-income countries was cut by US$1.69bn (£1.2bn) (House of Commons: Foreign Affairs Committee 2020; Mitchell,

Hughes, and Ritchie 2021). Prior to these changes, DFID was a key donor to NTD programmes, for example pledging US$271m (£195 m) towards MDA implementation during the London Declaration (Watts 2017).

In addition to political changes, global insecurity has highlighted weaknesses in the current model of MDA implementation. With the SARS-CoV2 pandemic, WHO, which manages the drug donations, recommended halting MDA as of 1st April 2020 (WHO 2020a). Mass drug administration is a vertical campaign that bypasses existing health systems (Chami and Bundy 2019). Although a cadre of volunteers, lay health workers, and primary school teachers are trained through MDA to distribute preventive chemotherapies, these medicines are often unavailable within peripheral primary health care (PHC) facilities. Without donated medicines available in local health systems, individuals infected with one or more STH were left untreated when MDA was halted since alternative options were unavailable. The COVID-19 pandemic has shown clearly the vulnerability of MDA alone because of its restricted access to medicines outside of scheduled campaigns.

Increasing country ownership of STH programmes is an important way forward to establishing a more sustainable treatment programme. The recently launched WHO 2021-2030 Road Map for NTDs emphasizes increasing country ownership, in particular exploring options for domestic financing (WHO 2020b). In line with bold new visions in the Road Map, this implies a need to 1) switch from treating specific diseases to treating people, 2) integrate treatment within local health care systems, and 3) increase country decision-making for STH treatment regimens/strategies. To achieve these objectives, alternatives to MDA are needed that align more closely with the principles of UHC, which aspires to make essential services always available and to ensure that when they are used, they do not result in financial hardship.

MDA does not equate with UHC

Mass drug administration often is used as a proxy indicator of UHC (Fitzpatrick et al. 2018). By providing essential health services at no cost to the end patient, MDA is one step towards providing essential health services for NTDs (Chami and Bundy 2019). However, using MDA as a proxy indicator of UHC may be misleading and masks the inequities present in the distribution of preventive chemotherapies and lack of control for the patient over their own treatment options (Dean et al. 2019). Endemic country financing options still need to be developed for medicine purchase and delivery through PHC facilities.

With current approaches to MDA the choice of when and where to receive treatment is not made by the patient. In many endemic settings, there are often no on-demand treatment options for STH. However it may now be possible to develop strategies for on-demand treatment for STH as prevalence decreases worldwide due to the successes of MDA (Montresor et al. 2020). The placement of medicines in PHC facilities to enable on-demand treatment raises a number of challenges and, in turn, future research opportunities. Open questions remain as to whether the donated medicines should be provided for use outside of vertical campaigns. In addition to promoting UHC and in-country ownership, there is a need to assess whether the individuals most in need of treatment would be reached through PHC facilities and whether this strategy is cost-effective, including the willingness-to-pay of participants for preventive chemotherapies or the willingness of national health systems to pay for diagnostics (Storey et al. 2019).

Rethinking infection mapping strategies

At a minimum, to make progress towards the placement of medicines in PHC facilities, new infection mapping strategies are needed that require a rethinking of the overall strategy. For example, they need not be reliant, as they are now, on administrative units (e.g. districts) or sampling of children in primary schools.

The target population for on-demand treatment access, focusing on the users of PHC, might arguably be primarily adults. Adults can have heavy infections with STH, especially hookworm, can play a major role in sustaining transmission in endemic communities, and perhaps most importantly, are in charge of the decisions and financial resources for bringing children to health facilities for treatment (Chami et al. 2018; 2015). This is in contrast to the current focus on school-aged children within primary schools for STH treatment (WHO 2006a).

This shift in thinking implies a need for new prevalence mapping strategies to measure STH prevalence within the catchment of the PHC facility. A list of communities served by a health centre, a spatial buffer such as a pre-defined radius from the health centre, or spatially regulated sampling (Fronterre et al. 2020) may be used to define catchment areas. After defining catchments, random sampling of eligible communities and individuals within those communities may be used to estimate STH prevalence. Cutting-edge approaches for spatial modelling, yet to be used by the NTD field, such as gravity models also may be applied to incorporate health care access within catchment definitions (Apparicio et al. 2008). Remarkably, travel times to a majority of government health centres across sub-Saharan Africa already have been estimated and are publicly available (Weiss et al. 2020). These revised implementation units for treatment programmes may guide the placement of preventive chemotherapies.

Towards patient-led, on-demand treatment

If STH treatment was available in PHC facilities, the next step to ensuring equitable access to treatment is to increase patient awareness. Campaigns have been underway to clearly communicate the definition of UHC, establish its purpose within countries, and provide technical knowledge (Holtz, Cox, and Cico 2018). In addition to the existing challenges of creating a common understanding and platform for UHC, STHs face the barrier of informing those who need treatment that on-demand options are available within PHC facilities. Health education campaigns will be needed to share the principles of UHC and to inform individuals of their right to request treatment for STH (Ediriweera et al. 2019; Montresor and Mupfasoni 2019). There is preliminary support for the demand for preventive chemotherapies outside of MDA (Dhakal et al. 2020). In Bangladesh, where only school-aged children were targeted for treatment, adults were found to experience a similar decline in prevalence when compared to treated children over a ten-year period. The authors speculate that this decline may be due to adults actively purchasing deworming medicines or improved WASH. To improve patient-led demand, other initiatives such as child health days, women's reproductive health clinics, and vaccine campaigns conducted through health centres might be coupled with the provision of deworming medicines to reach at-risk individuals.

Importantly, in STH-endemic areas, individuals who seek care from government health centres have been shown to differ in terms of socioeconomic status and WASH behaviours than individuals who seek care from traditional healers, private clinics, or seek no care at all (Chami et al. 2018). This implies that those most likely to be infected with STH are also less likely to seek treatment. This has the potential to undermine a patient-led process. Working with local communities and working with community leaders to advocate on-demand treatment should be investigated as a method to increase patient awareness and address inequalities related to who seeks treatment (Valente and Pumpuang 2007).

Improved health information systems to support UHC

Health Management Information Systems (HMIS) are improving in low-income countries. For example, the MalariaCare Electronic Data System used across Africa has enabled data entry at the district level with guided software platforms to reduce data entry time and errors (Burnett et al. 2019). A similar platform

might be developed for 1) STH catchment mapping, 2) the tracking of medicines delivered from national medical stores, and 3) record keeping of medicines administered to patients. At the very least, results from NTD registers that are used to track STH campaigns should be shared with HMIS, particularly by training existing HMIS staff to handle MDA data (as is being done with ESPEN).

Digital health approaches have shown promise for improving data management of STH in PHC facilities. Mobile notifications already have been widely used for lymphatic filariasis (and the distribution of albendazole) (Stanton et al. 2016; Tilahun et al. 2021). Text messaging and mobile applications have assisted in tracking albendazole medicine supplies, confirming patient treatment receipt, and providing health care information. Biometric technology, e.g. fingerprint scanning, in the Geshiyaro Study in Ethiopia has been used to verify treatment receipt in MDA campaigns for STH (Mekete et al. 2019). In addition to data management and patient outreach, a move towards systems thinking may assist in strengthening local health systems.

Future research is needed for UHC integration

Such an approach would require acknowledging that 'quick hit' solutions to STH are no longer plentiful (having been achieved by MDA), and that STH treatment can no longer be reduced to only MDA. Instead, complexity should be embraced by acknowledging the changing international landscape, patient needs, and dynamic health systems within endemic countries. For on-demand treatment in PHC facilities, there is a need to revise the understanding of the epidemiology of STH. Repeated MDA has been shown to miss individuals systematically, thereby introducing heterogeneity into the known distribution of infections within endemic communities (Basáñez et al. 2012; Chami et al. 2017; 2016). In particular, community-based distribution of albendazole in the context of areas co-endemic with lymphatic filariasis and STHs has been shown to miss the most marginalized individuals of low socioeconomic status and with limited access to adequate sanitation and safe water. These individuals are the most likely to be infected with STH. As these characteristics also represent individuals who also are less likely to seek care from government health centres (Chami et al. 2018), the need to monitor these characteristics in PHC facilities is twofold. Observable characteristics of poor socioeconomic status and inadequate WASH may be used to redefine at-risk groups for STH within PHC facilities. Simple characteristics such as home quality, drinking water source, and latrine ownership might be used to identify the groups for treatment through blanket or test-and-test strategies. One step towards inclusion of these social determinants of treatment would be to trial the collection of different indicators across countries where MDA is ongoing. The feasibility and applicability of observable characteristics could be systematically identified in future research to assess the evidence for UHC integration by piloting the collection of this information in NTD registers, holding focus groups in endemic communities, and conducting key informant interviews (e.g. with district health officers or primary school teachers).

Conclusions

This chapter has undertaken a sequential analysis of the global development of deworming programmes. We have discussed the evolution of policy, the translation of policy into programming, the measurement of the impact and cost of the programmes, and explored what might come next. In this final section we offer some concluding thoughts on each of these topics.

The evolution of policy: There has been recognition of worms as a health issue for thousands of years, but it is only in the last 100 years that there have been concerted public health responses. The "modern" approach to deworming, with a focus on specific treatments delivered at large scale to at risk populations first emerged in the 1980s, some forty years ago, and reached the status of broad consensus in the mid-2000s. The consensus was around Mass Drug Administration, with effective pharmaceuticals delivered through schools to school-age children without individual diagnosis, in communities shown by prior screening to have infection prevalence greater than 20%. While many countries went ahead with their own programmes, it was only eight years ago, in 2012, that a global effort was launched, and only in the last five years that programmes have been implemented at global scale.

This then is a story of success. We would remark on two points. First, this seems like a long time for the roll out of a seemingly very simple intervention; change in global health policy comes slowly. Secondly, and perhaps worryingly, the main pharmaceuticals used are based on products first discovered for veterinary applications, and there has been no break-through deworming drug for human or veterinary use discovered in the last 30 years.

The translation of policy into programmes: The 2012 "London Declaration on NTDs" was a watershed moment in the global roll-out of the deworming programmes, driven by the availability of donated treatments by the pharmaceutical industry. This has become the largest public health donation programme in human history, and the mobilization of drugs during 2018 was recognized as such by the Guinness Book of World Records. School-based MDA has been adopted by nearly all the countries where STH infection is endemic at levels considered to be of public health consequence. Some 3.3 billion treatments have been delivered to school-age children through schools since 2010. Some countries have stopped treatment, but for a majority of the worst affected the focus now is on identifying a threshold, based on "Elimination as a Public Health Problem" or "Interruption of Transmission," that will allow countries to scale back their programmes and to transition to sustainable, self-reliant programmes supported by domestic financing.

Measuring the impact of programmes: For many public health practitioners their awareness of deworming may be largely as spectators of the "worm wars". Today, the apparently conflicting interpretations of the evidence seem to have converged in some sense: There is a consensus clinically and in the meta-analyses that infected children should be treated. All recent meta-analyses find that there is large heterogeneity in impact, with significant effects in some trials and settings, and minimal effects in others (consistent with the clinical understanding of STH infection). There appears to be common ground around the justification for presumptively treating high prevalence populations (i.e. where average infection rates are 80-100%). Conversely it is also likely consensus that it does not make sense to conduct MDA in populations with low prevalence and very few to no highly infected children. The policy question globally is where to place the threshold. This helps reframe the debate over statistical evidence into a policy decision problem: how should a policy maker with a given level of helminth prevalence think about deworming policies, taking into account expected value, cost, and equity?

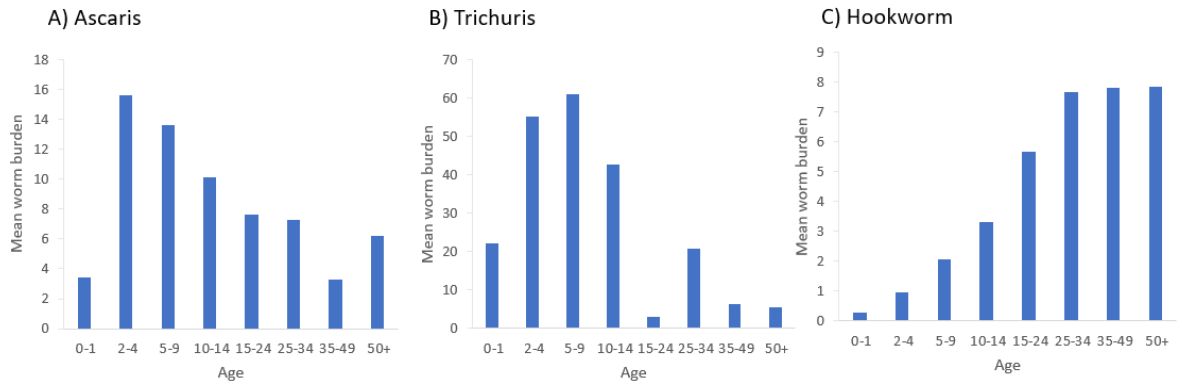
Assessing the costs and benefits of programmes: Analyses show that the current deworming strategies are cost-effective and value for money. This appears to hold even if the cost of procuring treatment is included. The programmes also appear to be cost-beneficial, although the current framework for estimating DALYs

does not fully summarise the disease burden, potentially underestimating the returns. There is a need to more comprehensively capture the health benefits of deworming, including quantifying if they are associated with excess mortality, and evaluating the non-health-related benefits of deworming, such as improved educational and economic outcomes. This will be particularly important in considering the potential costs and benefits of broadening MDA coverage to whole communities. As programmes evolve away from standalone vertical programmes, decision-makers need to consider the cost-effectiveness of integrated NTD control programme packages, and should account for the potential returns from building on established health system platforms and primary health care (PHC) facilities to deliver treatments, particularly to adults.

Rethinking deworming as an integrated part of health systems: Deworming programmes have become among the most ubiquitous and cost-effective public health programmes worldwide. This has taken a long time to happen, in terms of conceptualizing the problem, developing the solution, and mobilizing resources, but in the end has become a success story benefitting billions of children. Looking forward however, it is clear that the current reliance on MDA, whether school based or not, presents major concerns about vulnerability to external shocks, such the cessation of the donations, and the consequences of such standalone programmes as countries strive to achieve Universal Health Care. It took some 40 years to develop and roll-out the MDA approach, it would be timely to start thinking now about what should replace it in the context of UHC.

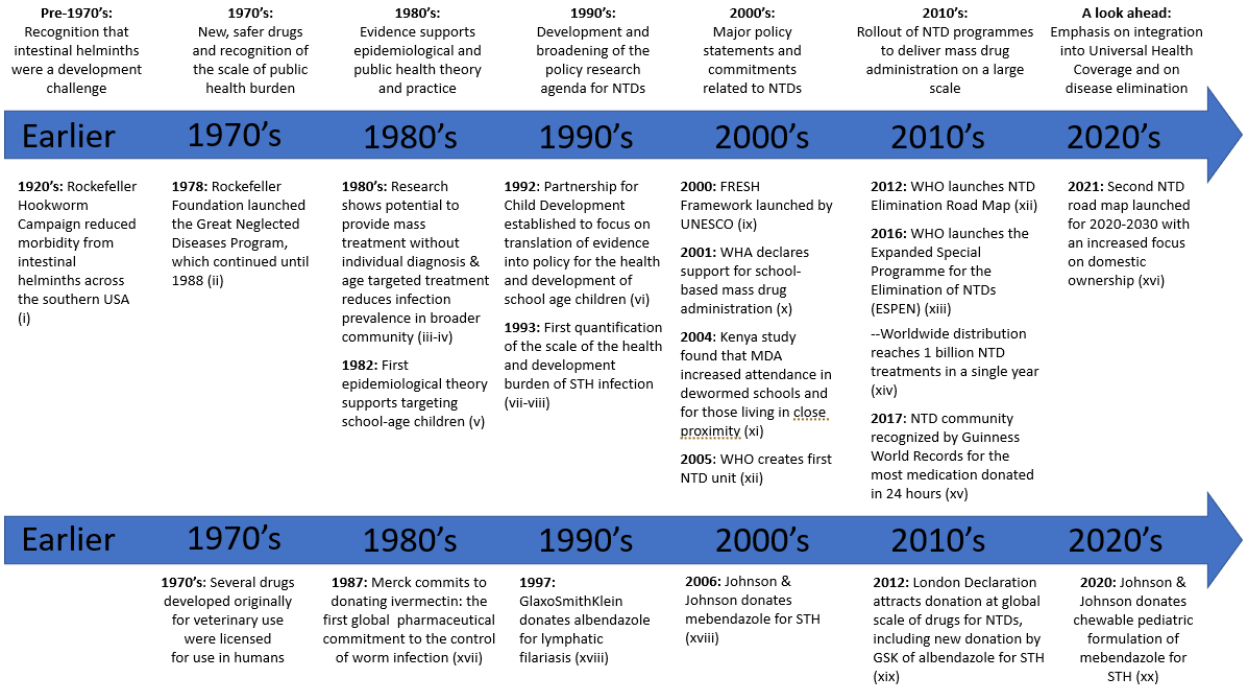
Figures

Fig. 1.1 Cross-sectional surveys of the mean intensity of infection in different age groupings for *Ascaris lumbricoides* (A), *Trichuris trichiura* (B), and hookworm (C) based on worm expulsion studies.



Source: Adapted from (Anderson et al. 2015)

Fig. 1.2 Timeline of milestones related to the epidemiological understanding of helminth infections, relevant policy measures, and pharmaceutical donations



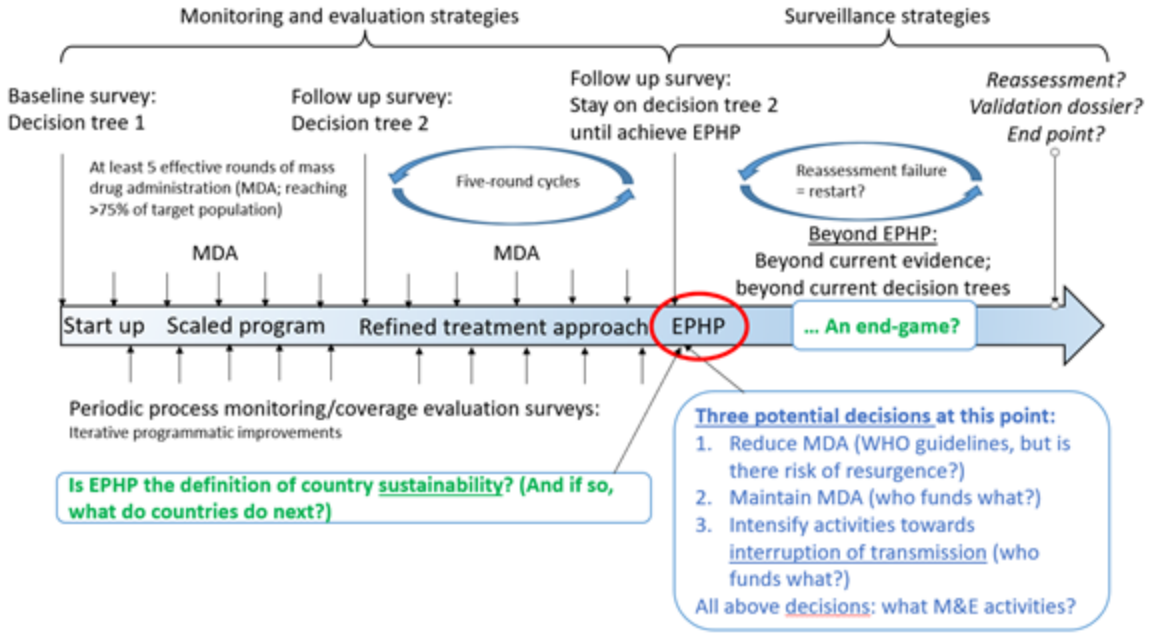
i. Ettling, John. 1981. "The Germ of Laziness." In *Rockefeller Philanthropy and Public Health in the New South*, 263. Cambridge, MA: Harvard University Press

ii. Keating C. Ken Warren and the Rockefeller foundation's great neglected diseases network, 1978–1988: The transformation of tropical and global medicine. Mol Med. 2014 Dec 16;20:S24–30.

iii. Bundy DAP. Control of intestinal nematode infections by chemotherapy: mass treatment versus diagnostic screening. Trans R Soc Trop Med Hyg. 1990;84(5):622–5.

iv. Bundy DAP, Wong MS, Lewis LL, Horton J. Control of geohelminths by delivery of targeted chemotherapy through schools. Trans R Soc Trop Med Hyg. 1990;84(1):115–20.
v. Anderson R, May R. Population dynamics of human helminth infections: Control by chemotherapy. Nature. 1982;297(5867):557–63.
vi. Partnership for Child Development. https://www.imperial.ac.uk/partnership-for-child-development/about-us/
vii. Warren K, Bundy D, Anderson R, Davis A, Henderson D, Jamison D. Helminth Infections. In: Disease Control Priorities in Developing Countries. 1st Edition. Oxford: Oxford University Press; 1993. p. 131–60.
viii. World Bank. World Development Report 1993: Investing in Health. World Development Report 1993. New York: Oxford University Press; 1993.
ix. Bundy D, Shaeffer S, Jukes M, Beegle K, Gillespie A, Drake L, et al. School-based health and nutrition programs. In: Jamison D, Brenanm J.G., Measham AR, Alleyne G, Claeson M, Evans D, et al., editors. Disease Control Priorities in Developing Countries. Second Edi. NY, USA: The World Bank / Oxford University Press; 2006. p. 1091–108.
x. WHA. Resolution 54.19 schistosomiasis and soil-transmitted helminth infections. Geneva, Switzerland; 2011.
xi. Miguel E, Kremer M. Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities. Econometrica. 2004 Jan;72(1):159–217.
xii. WHO. Accelerating Work to Overcome the Global Impact of Neglected Tropical Diseases: A Roadmap for Implementation. Geneva, Switzerland; 2012.
xiii. WHO Africa. ESPEN – New initiative to tackle neglected tropical diseases in Africa. 2015. Available from: https://www.afro.who.int/news/espen-new-initiative-tackle-neglected-tropical-diseases-africa
xiv. Uniting to Combat NTDs. Executive summary: Beating 10 diseases, reaching a billion people. 2016. Available from: https://unitingtocombatntds.org/reports/5th-report/executive-summary/
xv. Guinness World Records. Most medication donated in 24 hours. 2017. Available from: https://www.guinnessworldrecords.com/world-records/439520-most-medication-donated-in-24-hours
xvi. WHO. Ending the neglect to attain the Sustainable Development Goals. Geneva, Switzerland: World Health Organization; 2020.
xvii. Sturchio JL. The Case of Ivermectin: Lessons and Implications for Improving Access to Care and Treatment in Developing Countries. Community Eye Heal. 2001;14(38):22–3.
xviii. Bradley M, Taylor R, Jacobson J, Guex M, Hopkins A, Jensen J, et al. Medicine donation programmes supporting the global drive to end the burden of neglected tropical diseases. Trans R Soc Trop Med Hyg. 2021 Jan 28;115(2):136–44.
xix. Uniting to Combat NTDs. London Declaration on Neglected Tropical Diseases. 2012.
xx. Johnson & Johnson. Johnson & Johnson Extends Long-Standing Donation Program to Support Global Effort to Tackle Intestinal Worms | Johnson & Johnson. 2019. Available from: https://www.jnj.com/johnson-johnson-extends-long-standing-donation-program-to-support-global-effort-to-tackle-intestinal-worms

Fig. 1.3 The need for an evidence-informed monitoring and evaluation framework



Tables

Table 1.1 Medicines donated by pharmaceutical companies to WHO for the control of preventive chemotherapy (PC-)NTDs

Company	Drug donated	Susceptible disease	Commitment
Merck & Co	Ivermectin (Mectizan)	Onchocerciasis and lymphatic filariasis	Since 1987: Unlimited supply until onchocerciasis is eliminated
			Since 1997: Unlimited supply until lymphatic filariasis is eliminated from Yemen and African continent in regions where lymphatic filariasis is co-endemic with onchocerciasis
			2018-2025: Up to 100 million treatments to eliminate lymphatic filariasis using WHO-recommended triple-therapy MDA in regions that are not co-endemic for onchocerciasis
GlaxoSmithKlein (GSK)	Albendazole	Lymphatic filariasis	Since 1997: Up to 600 million tablets annually until lymphatic filariasis is eliminated as a public health problem
		STH	2012-2020: 400 million tablets annually for the treatment of STH in school-age children
Pfizer	Azithromycin	Trachoma	Since 1998-2025: Unlimited quantity to eliminate trachoma as a public health problem
Johnson & Johnson	Mebendazole	STH	2006-2025: Initially 50 million annual donation, revised to 200 million annual donation in 2010, for the treatment of STH in school-age children. From 2020, Johnson & Johnson is donating its chewable paediatric formulation, which can be safely used by preschool-age children.
Merck KgaA	Praziquantel	Schistosomiasis	Since 2007: Initially up to 200 million tablets to treat schistosomiasis in school-age children; commitment revised to an unlimited donation in 2017, until schistosomiasis is eliminated as a public health problem

Source: Adapted from (Bradley et al. 2021) with additional information from (Johnson & Johnson 2019)

Table 1.2 Hypothetical case study of the estimated financial costs of using different treatment strategies within the Kenyan national STH control programme

Strategy	Number treated	Assumed cost per treatment (US$)	Estimated total financial cost per year (US$)
School-based treatment	6 million children (Hodges 2017)	0.30[b]-0.56[c]	1.8-3.4 million
Community-wide treatment	14 million individuals[a]	0.32[d]-0.46[e]	4.4-6.4 million

[a] *Approximated based on demographic data from the World Bank* (World Bank, n.d.).
[b] *Based on the WHO MDA cost benchmark model* (Fitzpatrick et al. 2016).
[c] *Estimate from Evidence action (a programmatic estimate for 2015)* (Hodges 2017).
[d] *Based on the estimate from the TUMIKIA trial* (Pullan et al. 2019)*: routine scenario (excluding the research costs) relating to whole county (i.e. estimate at scale). US$0.025 per treatment was added for the cost of albendazole.*
[e] *Based on the estimate from the TUMIKIA trial* (Pullan et al. 2019) *– routine scenario (excluding the research costs) relating to trial areas only. US$0.025 per treatment was added for the cost of albendazole.*

Source: Adapted from (Turner and Bundy 2020)

Table 1.3 The cost per disability-adjusted life year (DALY) averted estimates relating to annual school-based deworming for STH

Study	Publication year	Intervention and setting	Approach used to estimate the effectiveness and time horizon	Assumed average costs of preventive chemotherapy	Average cost-effectiveness ratio per DALY averted	Cost year
Soil-transmitted helminthiases (STH):						
Chan *et al*. (Chan 1997)	1997	Mass treating SAC against *A. lumbricoides* – within a high prevalence community (timeframe for the intervention: 10 years)	Dynamic transmission model (time horizon: 10 years)	US$1,600 to treat the schoolchildren per 100,000 population in China	US$8	Unclear
Miguel and Kremer (Miguel and Kremer 2004)	2004	Biannual mass school-based treatment – given within a project in Kenya (timeframe for the intervention: 1 year)	Based on project data (time horizon: 1 year)	Based on US$0.49 per pupil per year (removing the costs related to praziquantel)	US$280 (per STH related DALY averted)	Unclear
Hotez *et al.* (DCP2) (Hotez, Bundy, et al. 2006)	2006	Annual mass school-based treatment – hypothetical setting (timeframe for the intervention: not clearly stated)	Back of the envelope (time horizon: not clearly stated)	Not stated	US$326.43 (note that within the report the results were reported as US$3.41 but there were errors within the calculation (GiveWell 2011b))	Unclear
GiveWell (GiveWell 2011a)	2011	Annual mass school-based treatment – hypothetical setting (timeframe for the intervention:	Back of the envelope (time horizon: one treatment round)	US$0.085 per treatment	US$82.54	Unclear

		one treatment round)				
Lo *et al.* (Lo et al. 2016)	2016	Annual mass school-based treatment – hypothetical setting (timeframe for the intervention: 5 years)	Dynamic transmission model (time horizon: 5 years)	US$0.53 per treatment (including drug costs)	20% prevalence in SAC: US$1077 60% prevalence in SAC: US$298 85% prevalence in SAC: US$174	2015
Schistosomiasis, lymphatic filariasis, and STH:						
De Neve *et al.* (De Neve et al. 2018)	2018	Annual mass school-based treatment – based on the PC programme in Madagascar (timeframe for the intervention: one treatment round)	Static model (time horizon: unclear)	Not directly reported	US$125 (95% uncertainty range: 65–231)	2013
Schistosomiasis and STH:						
Warren *et al*. (DCP1) (Warren et al. 1993)	1993	Hypothetical setting (timeframe for the intervention: 10 years)	Static calculation (time horizon: 10 years)	US$0.8-1.80 per child per year (including drug costs)	US$6–33	Unclear
Miguel and Kremer (Miguel and Kremer 2004)	2004	Annual mass school-based treatment for schistosomiasis and biannual mass school-based treatment for STH – given within a project in Kenya (timeframe for the intervention: 1 year)	Based on project data (time horizon: 1 year)	US$ 0.49 per pupil per year (including drug costs)	US$5 (99% of the benefit was due to averted schistosomiasis)	Unclear
Lo *et al*. (Lo et al. 2015)	2015	Annual mass school-based treatment –	Dynamic transmission model (time	US$0.71 per treatment	US$118 (US$87-140) (92% of the	2014

		within four communities in Côte d'Ivoire (timeframe for the intervention: 15 years)	horizon: 15 years)	(including drug costs)	disability resulted from *Schistosoma spp.* infections)	

It was not possible to adjust the different studies for inflation and they are reported in their original cost year (Turner, Lauer, et al. 2019).
DALY: Disability-adjusted life year, DCP1: Disease control priorities in developing countries (first edition), DCP2: Disease control priorities in developing countries (second edition), SAC: School-aged children, STH: Soil-transmitted helminthiases.

Source: Adapted from (Turner et al., n.d.)

References

Ahuja, Amrita, Sarah Baird, Joan Hamory Hicks, Michael Kremer, and Edward Miguel. 2017. "Economics of Mass Deworming Programs." In *Disease Control Priorities, Third Edition (Volume 8): Child and Adolescent Health and Development*, edited by Donald A.P. Bundy, Nilanthi de Silva, Susan Horton, Dean T Jamison, and George C Patton, 3rd ed., 413–22. Washington, DC: World Bank Group. https://doi.org/10.1596/978-1-4648-0423-6_ch29.

Aiken, Alexander M., Calum Davey, James R. Hargreaves, and Richard J. Hayes. 2015. "Re-Analysis of Health and Educational Impacts of a School-Based Deworming Programme in Western Kenya: A Pure Replication." *International Journal of Epidemiology* 44 (5): 1572–80. https://doi.org/10.1093/ije/dyv127.

Anderson, Roy M., Hugo C. Turner, James E. Truscott, T. Déirdre Hollingsworth, and Simon J. Brooker. 2015. "Should the Goal for the Treatment of Soil Transmitted Helminth (STH) Infections Be Changed from Morbidity Control in Children to Community-Wide Transmission Elimination?" Edited by Serap Aksoy. *PLOS Neglected Tropical Diseases* 9 (8): e0003897. https://doi.org/10.1371/journal.pntd.0003897.

Anderson, Roy, and Robert May. 1982. "Population Dynamics of Human Helminth Infections: Control by Chemotherapy." *Nature* 297 (5867): 557–63. https://doi.org/10.1038/297557a0.

Anderson, Roy, James Truscott, and T Deirdre Hollingsworth. 2014. "The Coverage and Frequency of Mass Drug Administration Required to Eliminate Persistent Transmission of Soil-Transmitted Helminths." *Phil. Trans. R. Soc.*, no. 369. https://doi.org/10.1098/rstb.2013.0435.

Apparicio, Philippe, Mohamed Abdelmajid, Mylène Riva, and Richard Shearmur. 2008. "Comparing Alternative Approaches to Measuring the Geographical Accessibility of Urban Health Services: Distance Types and Aggregation-Error Issues." https://doi.org/10.1186/1476-072X-7-7.

Ásbjörnsdóttir, Kristjana Hrönn, Sitara S. Rao Ajjampur, Roy M. Anderson, Robin Bailey, Iain Gardiner, Katherine E. Halliday, Moudachirou Ibikounle, et al. 2018. "Assessing the Feasibility of Interrupting the Transmission of Soil-Transmitted Helminths through Mass Drug Administration: The DeWorm3 Cluster Randomized Trial Protocol." Edited by Amadou Garba. *PLOS Neglected Tropical Diseases* 12 (1): e0006166. https://doi.org/10.1371/journal.pntd.0006166.

Baird, Sarah, George Washington University, Joan Hamory Hicks, Michael Kremer, Harvard University, Nber Edward Miguel, Kevin Audi, et al. 2016. "Worms at Work: Long-Run Impacts of a Child Health Investment."

Bangert, Mathieu, Pilar Bancalari, Denise Mupfasoni, Alexei Mikhailov, Albis F. Gabrielli, and Antonio Montresor. 2019. "Provision of Deworming Intervention to Pregnant Women by Antenatal Services in Countries Endemic for Soil-Transmitted Helminthiasis." *PLoS Neglected Tropical Diseases* 13 (5). https://doi.org/10.1371/journal.pntd.0007406.

Basáñez, María-Gloria, Michael D. French, Martin Walker, and Thomas S. Churcher. 2012. "Paradigm Lost: How Parasite Control May Alter Pattern and Process in Human Helminthiases." *Trends in Parasitology* 28 (4): 161–71. https://doi.org/10.1016/j.pt.2012.02.004.

Bleakley, Hoyt. 2007. "Disease and Development: Evidence from Hookworm Eradication in the American South." *Quarterly Journal of Economics* 122 (1): 73–117. https://doi.org/10.1162/qjec.121.1.73.

Boselli, Giulia, Aya Yajima, Padmasiri Eswara Aratchige, Keith Ernest Feldon, Anonh Xeuatvongsa, Kongxay Phounphenghak, Khampiou Sihakhang, et al. 2011. "Integration of Deworming into an

Existing Immunisation and Vitamin A Supplementation Campaign Is a Highly Effective Approach to Maximise Health Benefits with Minimal Cost in Lao PDR." *International Health* 3: 240–45. https://doi.org/10.1016/j.inhe.2011.08.002.

Bradley, Mark, Rachel Taylor, Julie Jacobson, Morgane Guex, Adrian Hopkins, Julie Jensen, Lynn Leonard, et al. 2021. "Medicine Donation Programmes Supporting the Global Drive to End the Burden of Neglected Tropical Diseases." *Transactions of The Royal Society of Tropical Medicine and Hygiene* 115 (2): 136–44. https://doi.org/10.1093/trstmh/traa167.

Bundy, Donald. 1990. "Control of Intestinal Nematode Infections by Chemotherapy: Mass Treatment versus Diagnostic Screening." *Transactions of the Royal Society of Tropical Medicine and Hygiene* 84 (5): 622–25. https://doi.org/10.1016/0035-9203(90)90126-Y.

———. 2011. *Rethinking School Health: A Key Component of Education for All*. Edited by Donald A.P. Bundy. Washington, DC: IBRD/World Bank. https://doi.org/10.1596/978-0-8213-7907-3.

Bundy, Donald A. P., Michael Kremer, Hoyt Bleakley, Matthew C. H. Jukes, and Edward Miguel. 2009. "Deworming and Development: Asking the Right Questions, Asking the Questions Right." Edited by Gavin Yamey. *PLoS Neglected Tropical Diseases* 3 (1): e362. https://doi.org/10.1371/journal.pntd.0000362.

Bundy, Donald, Laura J. Appleby, Mark Bradley, Kevin Croke, T. Deirdre Hollingsworth, Rachel Pullan, Hugo C. Turner, and Nilanthi de Silva. 2018. "100 Years of Mass Deworming Programmes: A Policy Perspective From the World Bank's Disease Control Priorities Analyses." In *Advances in Parasitology*, 100:127–54. Academic Press. https://doi.org/10.1016/bs.apar.2018.03.005.

Bundy, Donald, Linda Schultz, Bachir Sarr, Louise Banham, Peter Colenso, and Lesley Drake. 2017. "The School as a Platform for Addressing Health in Middle Childhood and Adolescence." In *Disease Control Priorities, Third Edition (Volume 8): Child and Adolescent Health and Development*, edited by Donald A.P. Bundy, Nilanthi de Silva, Susan Horton, Dean T Jamison, and George Patton, Third, 269–85. Washington, DC: IBRD/World Bank. https://doi.org/10.1596/978-1-4648-0423-6_ch20.

Bundy, Donald, Sheldon Shaeffer, Matthew Jukes, Kathleen Beegle, Amaya Gillespie, Lesley Drake, Anna-Maria Frances Lee, Seung-hee Hoffman, et al. 2006. "School-Based Health and Nutrition Programs." In *Disease Control Priorities in Developing Countries*, edited by D. Jamison, Brenanm J.G., A.R. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, Second Edi, 1091–1108. NY, USA: The World Bank / Oxford University Press. http://files.dcp2.org/pdf/expressbooks/prevent.pdf#page=78.

Burnett, Sarah M, Jolene Wun, Illah Evance, Kelly M Davis, Graham Smith, Cristina Lussiana, Goodluck Tesha, et al. 2019. "Introduction and Evaluation of an Electronic Tool for Improved Data Quality and Data Use during Malaria Case Management Supportive Supervision." *Am. J. Trop. Med. Hyg* 100 (4): 889–98. https://doi.org/10.4269/ajtmh.18-0366.

Campbell, Suzy J., Susana V. Nery, James S. McCarthy, Darren J. Gray, Ricardo J. Soares Magalhães, and Archie C.A. Clements. 2016. "A Critical Appraisal of Control Strategies for Soil-Transmitted Helminths." *Trends in Parasitology*. Elsevier Ltd. https://doi.org/10.1016/j.pt.2015.10.006.

Campbell, Suzy J., Georgia B. Savage, Darren J. Gray, Jo-An M. Atkinson, Ricardo J. Soares Magalhães, Susana V. Nery, James S. McCarthy, et al. 2014. "Water, Sanitation, and Hygiene (WASH): A Critical Component for Sustainable Soil-Transmitted Helminth and Schistosomiasis Control." Edited by Xiao-Nong Zhou. *PLoS Neglected Tropical Diseases* 8 (4): e2651. https://doi.org/10.1371/journal.pntd.0002651.

Campbell, Suzy J, Mike Y Osei-Atweneboana, Russell Stothard, Artemis Koukounari, Lucas Cunningham, Samuel K Armoo, Nana-Kwadwo Biritwum, et al. 2018. “Tropical Medicine and Infectious Disease The COUNTDOWN Study Protocol for Expansion of Mass Drug Administration Strategies against Schistosomiasis and Soil-Transmitted Helminthiasis in Ghana.” *Trop. Med. Infect. Dis* 3: 10. https://doi.org/10.3390/tropicalmed3010010.

Chami, Goylette F., Alan Fenwick, Erwin Bulte, Andreas A. Kontoleon, Narcis B. Kabatereine, Edridah M. Tukahebwa, and David W. Dunne. 2015. “Influence of Schistosoma Mansoni and Hookworm Infection Intensities on Anaemia in Ugandan Villages.” *PLoS Neglected Tropical Diseases* 9 (10). https://doi.org/10.1371/journal.pntd.0004193.

Chami, Goylette F., Andreas A. Kontoleon, Erwin Bulte, Alan Fenwick, Narcis B. Kabatereine, Edridah M. Tukahebwa, and David W. Dunne. 2016. “Profiling Nonrecipients of Mass Drug Administration for Schistosomiasis and Hookworm Infections: A Comprehensive Analysis of Praziquantel and Albendazole Coverage in Community-Directed Treatment in Uganda.” *Clinical Infectious Diseases* 62 (2): 200–207. https://doi.org/10.1093/cid/civ829.

———. 2017. “Community-Directed Mass Drug Administration Is Undermined by Status Seeking in Friendship Networks and Inadequate Trust in Health Advice Networks.” *Social Science and Medicine* 183: 37–47. https://doi.org/10.1016/j.socscimed.2017.04.009.

Chami, Goylette F, and Donald AP Bundy. 2019. “More Medicines Alone Cannot Ensure the Treatment of Neglected Tropical Diseases.” *Lancet Infect Dis*. https://doi.org/10.1016/S1473-3099(19)30160-4.

Chami, Goylette F, Narcis B Kabatereine, Edridah M Tukahebwa, and David W Dunne. 2018. “Precision Global Health and Comorbidity: A Population-Based Study of 16 357 People in Rural Uganda.” *J. R. Soc. Interface* 15. https://doi.org/10.1098/rsif.2018.0248.

Chan, Man Suen. 1997. “The Global Burden of Intestinal Nematode Infections - Fifty Years On.” *Parasitology Today* 13 (11): 438–43. https://doi.org/10.1016/S0169-4758(97)01144-7.

CIFF. 2020. “Deworming Innovation Fund.” 2020. https://ciff.org/grant-portfolio/deworming-innovation-fund/.

Conteh, Lesong, Thomas Engels, and David H Molyneux. 2010. “Socioeconomic Aspects of Neglected Tropical Diseases.” *The Lancet* 375: 239–47. https://doi.org/10.1016/S0140-6736(09)61422-7.

Croke, Kevin, and Rifat Atun. 2019. “The Long Run Impact of Early Childhood Deworming on Numeracy and Literacy: Evidence from Uganda.” https://doi.org/10.1371/journal.pntd.0007085.

Croke, Kevin, Joan Hamory Hicks, Eric Hsu, Michael Kremer, and Edward Miguel. 2017. “Should the WHO Withdraw Support for Mass Deworming?” *PLoS Neglected Tropical Diseases* 11 (6). https://doi.org/10.1371/journal.pntd.0005481.

Crompton, D. W.T., and R. R. Whitehead. 1993. “Hookworm Infections and Human Iron Metabolism.” *Parasitology* 107 (S1): s137-S145. https://doi.org/10.1017/S0031182000075569.

Dean, Laura, Kim Ozano, Oluwatosin Adekeye, Ruth Dixon, Ebua Gallus Fung, Margaret Gyapong, Sunday Isiyaku, et al. 2019. “Neglected Tropical Diseases as a ‘Litmus Test’ for Universal Health Coverage? Understanding Who Is Left behind and Why in Mass Drug Administration: Lessons from Four Country Contexts.” Edited by Arianna R. Means. *PLOS Neglected Tropical Diseases* 13 (11): e0007847. https://doi.org/10.1371/journal.pntd.0007847.

Dhakal, Sanjaya, Mohammad Jahirul KarimID, Abdullah Al Kawsar, Jasmine IrishID, Mujibur Rahman, Cara TuppsID, Ashraful Kabir, and Rubina ImtiazID. 2020. “Post-Intervention Epidemiology of

STH in Bangladesh: Data to Sustain the Gains." https://doi.org/10.1371/journal.pntd.0008597.

Ediriweera, Dileepa Senajith, Sharmini Gunawardena, Nipul Kithsiri Gunawardena, Devika Iddawela, Selvam Kannathasan, Arumugam Murugananthan, Channa Yahathugoda, Arunasalam Pathmeswaran, Peter John Diggle, and Nilanthi de Silva. 2019. "Reassessment of the Prevalence of Soil-Transmitted Helminth Infections in Sri Lanka to Enable a More Focused Control Programme: A Cross-Sectional National School Survey with Spatial Modelling." *The Lancet Global Health* 7 (9): e1237–46. https://doi.org/10.1016/S2214-109X(19)30253-0.

Espinal, Marcos, Margaret E Kruk, Madame Cisse, Mariama Mohamed, and Emily Wainwright. 2021. "Considerations for a Sustainability Framework for Neglected Tropical Diseases Programming." *Trans R Soc Trop Med Hyg* 115: 176–78. https://doi.org/10.1093/trstmh/traa196.

Ettling, John. 1981. "The Germ of Laziness." In *Rockefeller Philanthropy and Public Health in the New South*, 263. Cambridge, MA: Harvard University Press.

Fitzpatrick, Christopher, Mathieu Bangert, Pamela Sabina Mbabazi, Alexei Mikhailov, Honorat Zouré, Maria Polo Rebollo, Magda Robalo Correia e Silva, and Gautam Biswas. 2018. "Monitoring Equity in Universal Health Coverage with Essential Services for Neglected Tropical Diseases: An Analysis of Data Reported for Five Diseases in 123 Countries over 9 Years." *The Lancet Global Health* 6 (9): e980–88. https://doi.org/10.1016/S2214-109X(18)30307-3.

Fitzpatrick, Christopher, Fiona M. Fleming, Matthew Madin-Warburton, Timm Schneider, Filip Meheus, Kingsley Asiedu, Anthony W. Solomon, Antonio Montresor, and Gautam Biswas. 2016. "Benchmarking the Cost per Person of Mass Treatment for Selected Neglected Tropical Diseases: An Approach Based on Literature Review and Meta-Regression with Web-Based Software Application." Edited by Hélène Carabin. *PLOS Neglected Tropical Diseases* 10 (12): e0005037. https://doi.org/10.1371/journal.pntd.0005037.

Fitzpatrick, Christopher, Uzoma Nwankwo, Edeltraud Lenk, Sake J. de Vlas, and Donald A. P. Bundy. 2017. "An Investment Case for Ending Neglected Tropical Diseases." In *Disease Control Priorities, Third Edition (Volume 6): Major Infectious Diseases*, 411–31. The World Bank. https://doi.org/10.1596/978-1-4648-0524-0_ch17.

Fronterre, Claudio, Benjamin Amoah, Emanuele Giorgi, Michelle C Stanton, and Peter J Diggle. 2020. "Design and Analysis of Elimination Surveys for Neglected Tropical Diseases." *The Journal of Infectious Diseases* 221 (Supplement_5): S554–60. https://doi.org/10.1093/infdis/jiz554.

Gabrielli, Albis Francesco. 2022. "Soil-Transmitted Helminthiasis." In *Helminth Infections and Their Impact on Global Public Health*, edited by Fabrizio Bruschi. Springer.

Gedge, Lukyn M, Alison A Bettis, Mark H Bradley, T Déirdre Hollingsworth, and Hugo C Turner. 2018. "Economic Evaluations of Lymphatic Filariasis Interventions: A Systematic Review and Research Needs." *Parasites and Vectors* 11 (75). https://doi.org/10.1186/s13071-018-2616-z.

GiveWell. 2011a. "Cost-Effectiveness in $/DALY for Deworming Interventions." 2011. https://www.givewell.org/international/technical/programs/deworming/cost-effectiveness.

———. 2011b. "Errors in DCP2 Cost-Effectiveness Estimate for Deworming." 2011. https://blog.givewell.org/2011/09/29/errors-in-dcp2-cost-effectiveness-estimate-for-deworming/.

Glenn, Jeffrey, Kimberly Kamara, Zaiyanatu Abubakar Umar, Teresa Chahine, Nils Daulaire, and Thomas Bossert. 2020. "Applied Systems Thinking: A Viable Approach to Identify Leverage Points for Accelerating Progress towards Ending Neglected Tropical Diseases." *Health Research Policy and Systems* 18 (56). https://doi.org/10.1186/s12961-020-00570-4.

Goldman, Ann S., Molly A. Brady, Abdel Direny, Luccene Desir, Roland Oscard, Jean Francois Vely, Mary Linehan, and Margaret Baker. 2011. "Costs of Integrated Mass Drug Administration for Neglected Tropical Diseases in Haiti." *American Journal of Tropical Medicine and Hygiene* 85 (5): 826–33. https://doi.org/10.4269/ajtmh.2011.10-0635.

Goldman, Ann S, Victoria H Guisinger, Moses Aikins, Maria Lourdes, E Amarillo, Vicente Y Belizario, Bertha Garshong, et al. 2007. "National Mass Drug Administration Costs for Lymphatic Filariasis Elimination." *PLoS Neglected Tropical Diseases* 1 (1): e67. https://doi.org/10.1371/journal.pntd.0000067.

Guinness World Records. 2017. "Most Medication Donated in 24 Hours." 2017. https://www.guinnessworldrecords.com/world-records/439520-most-medication-donated-in-24-hours.

Hall, Andrew, Gillian Hewitt, Veronica Tuffrey, and Nilanthi De Silva. 2008. "A Review and Meta-Analysis of the Impact of Intestinal Worms on Child Growth and Nutrition." *Maternal and Child Nutrition* 4: 118–236.

Hasegawa, Mitsuko, Nils Pilotte, Mihoko Kikuchi, Arianna R. Means, Marina Papaiakovou, Andrew M. Gonzalez, Jacqueline R.M.A. Maasch, et al. 2020. "What Does Soil-Transmitted Helminth Elimination Look like? Results from a Targeted Molecular Detection Survey in Japan." *Parasites and Vectors* 13 (1): 6. https://doi.org/10.1186/s13071-019-3875-z.

Hernando, Yolanda, Kaela Colwell, and Brian D. Wright. 2016. "Doing Well While Fighting River Blindness: The Alignment of a Corporate Drug Donation Programme with Responsibilities to Shareholders." *Tropical Medicine & International Health* 21 (10): 1304–10. https://doi.org/10.1111/tmi.12759.

Hicks, Joan Hamory, Edward Miguel, Michael Walker, Michael Kremer, and Sarah Baird. 2021. "Twenty-Year Economic Impacts of Deworming." *PNAS* 118 (14). https://doi.org/10.1073/pnas.2023185118/-/DCSupplemental.y.

Hodges, Liam Chan. 2017. "Costs of School-Based Deworming: A Best-Buy Development Intervention - Evidence Action." Evidence Action. 2017. https://www.evidenceaction.org/deworm-cost-per-child/.

Holtz, Jeanna, Betty Cox, and Altea Cico. 2018. "Building Momentum for Universal Health Coverage." Washington, DC. https://lhssproject.org/building-momentum-for-universal-health-coverage.

Hong, Sung Tae, Jong Yil Chai, Min Ho Choi, Sun Huh, Han Jong Rim, and Soon Hyung Lee. 2006. "A Successful Experience of Soil-Transmitted Helminth Control in the Republic of Korea." *Korean J Parasitology* 44 (3): 177–85. https://doi.org/10.3347/kjp.2006.44.3.177.

Hotez, Peter J., Donald A. P. Bundy, Kathleen Beegle, Simon Brooker, Lesley Drake, Nilanthi de Silva, Antonio Montresor, et al. 2006. "Helminth Infections: Soil-Transmitted Helminth Infections and Schistosomiasis." In *Disease Control Priorities in Developing Countries*, edited by DT Jamison, JG Breman, and AR Measham, Second Edi, 467–82. Washington, DC: The International Bank for Reconstruction and Development / The World Bank. http://www.ncbi.nlm.nih.gov/pubmed/21250326.

Hotez, Peter J., David H. Molyneux, Alan Fenwick, Eric Ottesen, Sonia Ehrlich Sachs, and Jeffrey D. Sachs. 2006. "Incorporating a Rapid-Impact Package for Neglected Tropical Diseases with Programs for HIV/AIDS, Tuberculosis, and Malaria: A Comprehensive pro-Poor Health Policy and Strategy for the Developing World." *PLoS Medicine*. Public Library of Science. https://doi.org/10.1371/journal.pmed.0030102.

House of Commons: Foreign Affairs Committee. 2020. “Merging Success: Bringing Together the FCO and DFID.” London. https://publications.parliament.uk/pa/cm5801/cmselect/cmfaff/809/80902.htm.

Johnson & Johnson. 2019. “Johnson & Johnson Extends Long-Standing Donation Program to Support Global Effort to Tackle Intestinal Worms | Johnson & Johnson.” 2019. https://www.jnj.com/johnson-johnson-extends-long-standing-donation-program-to-support-global-effort-to-tackle-intestinal-worms.

Liu, Chengfang, Louise Lu, Linxiu Zhang, Renfu Luo, Sean Sylvia, Alexis Medina, Scott Rozelle, Darvin Scott Smith, Yingdan Chen, and Tingjun Zhu. 2017. “Effect of Deworming on Indices of Health, Cognition, and Education among Schoolchildren in Rural China: A Cluster-Randomized Controlled Trial.” *Am. J. Trop. Med. Hyg* 96 (6): 1478–89. https://doi.org/10.4269/ajtmh.16-0354.

Lo, Nathan C., Isaac I. Bogoch, Brian G. Blackburn, Giovanna Raso, Eliézer K. N’Goran, Jean T. Coulibaly, Sören L. Becker, Howard B. Abrams, Jürg Utzinger, and Jason R. Andrews. 2015. “Comparison of Community-Wide, Integrated Mass Drug Administration Strategies for Schistosomiasis and Soil-Transmitted Helminthiasis: A Cost-Effectiveness Modelling Study.” *Lancet Global Health* 3 (October): e629–38. https://doi.org/10.1016/S2214-109X(15)00047-9.

Lo, Nathan C., Ying Si Lai, Dimitrios Alexios Karagiannis-Voules, Isaac I. Bogoch, Jean T. Coulibaly, Eran Bendavid, Jürg Utzinger, Penelope Vounatsou, and Jason R. Andrews. 2016. “Assessment of Global Guidelines for Preventive Chemotherapy against Schistosomiasis and Soil-Transmitted Helminthiasis: A Cost-Effectiveness Modelling Study.” *The Lancet Infectious Diseases* 16 (9): 1065–75. https://doi.org/10.1016/S1473-3099(16)30073-1.

Luby, Stephen P., Mahbubur Rahman, Benjamin F. Arnold, Leanne Unicomb, Sania Ashraf, Peter J. Winch, Christine P. Stewart, et al. 2018. “Effects of Water Quality, Sanitation, Handwashing, and Nutritional Interventions on Diarrhoea and Child Growth in Rural Bangladesh: A Cluster Randomised Controlled Trial.” *The Lancet Global Health* 6 (3): e302–15. https://doi.org/10.1016/S2214-109X(17)30490-4.

Mekete, Kalkidan, Alison Ower, Julia Dunn, Heven Sime, Gemechu Tadesse, Ebba Abate, Nebiyu Nigussu, et al. 2019. “The Geshiyaro Project: A Study Protocol for Developing a Scalable Model of Interventions for Moving towards the Interruption of the Transmission of Soil-Transmitted Helminths and Schistosome Infections in the Wolaita Zone of Ethiopia.” *Parasites & Vectors* 12 (503). https://doi.org/10.1186/s13071-019-3757-4.

Miguel, Edward, and Michael Kremer. 2004. “Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities.” *Econometrica* 72 (1): 159–217. https://doi.org/10.1111/j.1468-0262.2004.00481.x.

Mitchell, Ian, Sam Hughes, and Euan Ritchie. 2021. “An Overview of the Impact of Proposed Cuts to UK Aid | Center For Global Development.” Center for Global Development. 2021. https://www.cgdev.org/publication/overview-impact-proposed-cuts-uk-aid.

Molyneux, David H, Peter J Hotez, and Alan Fenwick. 2005. “‘Rapid-Impact Interventions’: How a Policy of Integrated Control for Africa’s Neglected Tropical Diseases Could Benefit the Poor.” *PLoS Medicine* 2 (11): e336. https://doi.org/10.1371/journal.pmed.0020336.

Montresor, Antonio, and Deniose Mupfasoni. 2019. “Achievements of the Deworming Programme in Sri Lanka.” *The Lancet Global Health*. Elsevier Ltd. https://doi.org/10.1016/S2214-109X(19)30309-2.

Montresor, Antonio, Denise Mupfasoni, Alexei Mikhailov, Pauline Mwinzi, Ana Lucianez, Mohamed Jamsheed, Elkan Gasimov, et al. 2020. “The Global Progress of Soil-Transmitted Helminthiases Control in 2020 and World Health Organization Targets for 2030.” *PLoS Neglected Tropical*

Diseases 14 (8): 1–17. https://doi.org/10.1371/journal.pntd.0008505.

Mwandawiro, Charles, Collins Okoyo, Jimmy Kihara, Elses Simiyu, Stella Kepha, Suzy J Campbell, Matthew C Freeman, Simon J Brooker, and Sammy M Njenga. 2019. "Results of a National School-Based Deworming Programme on Soil-Transmitted Helminths Infections and Schistosomiasis in Kenya: 2012-2017." *Parasites and Vectors* 12 (76): 1–18. https://doi.org/10.1186/s13071-019-3322-1.

Neve, Jan Walter De, Rija L. Andriantavison, Kevin Croke, Johannes Krisam, Voahirana H. Rajoela, Rary A. Rakotoarivony, Valérie Rambeloson, Linda Schultz, Jumana Qamruddin, and Stéphane Verguet. 2018. "Health, Financial, and Education Gains of Investing in Preventive Chemotherapy for Schistosomiasis, Soil-Transmitted Helminthiases, and Lymphatic Filariasis in Madagascar: A Modeling Study." *PLoS Neglected Tropical Diseases* 12 (12): 1–17. https://doi.org/10.1371/journal.pntd.0007002.

Null, Clair, Christine P Stewart, Amy J Pickering, Holly N Dentz, Benjamin F Arnold, Charles D Arnold, Jade Benjamin-Chung, et al. 2018. "Articles Effects of Water Quality, Sanitation, Handwashing, and Nutritional Interventions on Diarrhoea and Child Growth in Rural Kenya: A Cluster-Randomised Controlled Trial." *Lancet Glob Health* 6: e316-29. https://doi.org/10.1016/S2214-109X(18)30005-6.

Owada, Kei, Mark Nielsen, Colleen L. Lau, Archie C.A. Clements, Laith Yakob, and Ricardo J. Soares Magalhães. 2017. "Measuring the Effect of Soil-Transmitted Helminth Infections on Cognitive Function in Children: Systematic Review and Critical Appraisal of Evidence." *Advances in Parasitology* 98: 1–37. https://doi.org/10.1016/bs.apar.2017.05.002.

Pullan, Rachel L., Katherine E. Halliday, William E. Oswald, Carlos Mcharo, Emma Beaumont, Stella Kepha, Stefan Witek-McManus, et al. 2019. "Effects, Equity, and Cost of School-Based and Community-Wide Treatment Strategies for Soil-Transmitted Helminths in Kenya: A Cluster-Randomised Controlled Trial." *The Lancet* 393 (10185): 2039–50. https://doi.org/10.1016/S0140-6736(18)32591-1.

Redekop, William K., Edeltraud J. Lenk, Marianne Luyendijk, Christopher Fitzpatrick, Louis Niessen, Wilma A. Stolk, Fabrizio Tediosi, et al. 2017. "The Socioeconomic Benefit to Individuals of Achieving the 2020 Targets for Five Preventive Chemotherapy Neglected Tropical Diseases." Edited by Paul J. Brindley. *PLOS Neglected Tropical Diseases* 11 (1): e0005289. https://doi.org/10.1371/journal.pntd.0005289.

Roodman, David. 2016. "Why I Mostly Believe in Worms." The GiveWell Blog. December 6, 2016. https://blog.givewell.org/2016/12/06/why-i-mostly-believe-in-worms/.

———. 2017. "How Thin the Reed? Generalizing from 'Worms at Work.'" The GiveWell Blog. January 4, 2017. https://blog.givewell.org/2017/01/04/how-thin-the-reed-generalizing-from-worms-at-work/.

———. 2018. "Comment: The Impacts of Hookworm Eradication in the American South." San Francisco.

Shahriar, Arman A., and Jonathan D. Alpern. 2020. "Antiparasitic Drugs in the United States—Two Roads to High Prices." *Frontiers in Sociology* 5 (October): 540478. https://doi.org/10.3389/fsoc.2020.540478.

Stanton, Michelle, Andrew Molineux, Charles Mackenzie, and Louise Kelly-Hope. 2016. "Mobile Technology for Empowering Health Workers in Underserved Communities: New Approaches to Facilitate the Elimination of Neglected Tropical Diseases." *JMIR Public Health and Surveillance* 2 (1). https://doi.org/10.2196/publichealth.5064.

Stiles, C.W., and P.E. Garrison. 1906. *A Statistical Study of the Prevalence of Intestinal Worms in Man*. US Government Printing Office.

Stoll, Norman R. 1947. "This Wormy World." *J. Paristol.* 33: 1–18.

Stoltzfus, Rebecca J., Marco Albonico, James M. Tielsch, Hababu M. Chwaya, and Lorenzo Savioli. 1997. "School-Based Deworming Program Yields Small Improvement in Growth of Zanzibari School Children after One Year." *Journal of Nutrition* 127 (11): 2187–93. https://doi.org/10.1093/jn/127.11.2187.

Storey, Helen L., Neha Agarwal, Jason Cantera, Allison Golden, Kerry Gallo, Tara Herrick, Vicente Belizario, et al. 2019. "Formative Research to Inform Development of a New Diagnostic for Soil-Transmitted Helminths: Going beyond the Laboratory to Ensure Access to a Needed Product." Edited by Ana Lourdes Sanchez. *PLOS Neglected Tropical Diseases* 13 (5): e0007372. https://doi.org/10.1371/journal.pntd.0007372.

Sturchio, Jeffrey L. 2001. "The Case of Ivermectin: Lessons and Implications for Improving Access to Care and Treatment in Developing Countries." *Community Eye Health* 14 (38): 22–23. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1705916/pdf/jceh_14_38_022.pdf.

Taylor-Robinson, DC, N Maayan, S Donegan, M Chaplin, and P Garner. 2019. "Public Health Deworming Programmes for Soil-Transmitted Helminths in Children Living in Endemic Areas (Review)." *Cochrane Database of Systematic Reviews*, no. 9: 172. https://doi.org/10.1002/14651858.CD000371.pub7.

Taylor-Robinson, DC, N Maayan, K Soares-Weiser, S Donegan, and P Garner. 2012. "Deworming Drugs for Soil-Transmitted Intestinal Worms in Children: Effects on Nutritional Indicators, Haemoglobin and School Performance (Review)." *Cochrane Database of Systematic Reviews*, no. 11: 143. http://www.thecochranelibrary.com.

———. 2015. "Deworming Drugs for Soil-Transmitted Intestinal Worms in Children: Effects on Nutritional Indicators, Haemoglobin, and School Performance (Review)." *Cochrane Database of Systematic Reviews*, no. 7: 160. https://doi.org/10.1002/14651858.CD000371.pub6.

The END Fund. 2020. "The END Fund Announces the Deworming Innovation Fund in Four African Countries on the Inaugural World NTD Day." 2020. https://www.prnewswire.com/news-releases/the-end-fund-announces-the-deworming-innovation-fund-in-four-african-countries-on-the-inaugural-world-ntd-day-300996147.html.

Tilahun, Binyam, Kassahun Dessie Gashu, Zeleke Abebaw Mekonnen, Berhanu Fikadie Endehabtu, and Dessie Abebaw Angaw. 2021. "Mapping the Role of Digital Health Technologies in the Case Detection, Management, and Treatment Outcomes of Neglected Tropical Diseases: A Scoping Review." *Tropical Medicine and Health* 49 (17). https://doi.org/10.1186/s41182-021-00307-1.

Truscott, J. E., H. C. Turner, S. H. Farrell, and R. M. Anderson. 2016. "Soil-Transmitted Helminths: Mathematical Models of Transmission, the Impact of Mass Drug Administration and Transmission Elimination Criteria." *Advances in Parasitology* 94: 133–98. https://doi.org/10.1016/bs.apar.2016.08.002.

Truscott, James E., T. Déirdre Hollingsworth, Simon J. Brooker, and Roy M. Anderson. 2014. "Can Chemotherapy Alone Eliminate the Transmission of Soil Transmitted Helminths?" *Parasites and Vectors* 7 (1): 266. https://doi.org/10.1186/1756-3305-7-266.

Turner, HC, WA Stolk, AW Solomon, JD King, A Montresor, and DH Molyneux. n.d. "Are Current Preventive Chemotherapy Strategies for Controlling and Eliminating Neglected Tropical Diseases

Cost-Effective?"

Turner, Hugo. 2021. "Health Economic Analyses of the Global Programme to Eliminate Lymphatic Filariasis." *International Health* 13 (Suppl.1): S71–74. https://doi.org/10.1093/inthealth/ihaa095.

Turner, Hugo C., Alison A. Bettis, Brian K. Chu, Deborah A. McFarland, Pamela J. Hooper, Eric A. Ottesen, and Mark H. Bradley. 2016. "The Health and Economic Benefits of the Global Programme to Eliminate Lymphatic Filariasis (2000-2014)." *Infectious Diseases of Poverty* 5 (54). https://doi.org/10.1186/s40249-016-0147-4.

Turner, Hugo C., Michael D. French, Antonio Montresor, Charles H. King, David Rollinson, and Jaspreet Toor. 2020. "Economic Evaluations of Human Schistosomiasis Interventions: A Systematic Review and Identification of Associated Research Needs." *Wellcome Open Research* 5 (45). https://doi.org/10.12688/wellcomeopenres.15754.2.

Turner, Hugo C., Jeremy A. Lauer, Bach Xuan Tran, Yot Teerawattananon, and Mark Jit. 2019. "Adjusting for Inflation and Currency Changes Within Health Economic Studies." *Value in Health* 22 (9): 1026–32. https://doi.org/10.1016/j.jval.2019.03.021.

Turner, Hugo C., Jaspreet Toor, TD. Hollingsworth, and Roy M. Anderson. 2018. "Economic Evaluations of Mass Drug Administration: The Importance of Economies of Scale and Scope." *Clinical Infectious Diseases* 66 (8): 1298–1303. https://doi.org/10.1093/cid/cix1001.

Turner, Hugo C., James E. Truscott, Alison A. Bettis, Kathryn V. Shuford, Julia C. Dunn, T. Déirdre Hollingsworth, Simon J. Brooker, and Roy M. Anderson. 2015. "An Economic Evaluation of Expanding Hookworm Control Strategies to Target the Whole Community." *Parasites and Vectors* 8 (570). https://doi.org/10.1186/s13071-015-1187-5.

Turner, Hugo C., Martin Walker, Sébastien D. S. Pion, Deborah A. McFarland, Donald A. P. Bundy, and María-Gloria Basáñez. 2019. "Economic Evaluations of Onchocerciasis Interventions: A Systematic Review and Research Needs." *Tropical Medicine & International Health* 24 (7): 788–816. https://doi.org/10.1111/tmi.13241.

Turner, Hugo C, Alison A Bettis, Brian K Chu, Deborah A Mcfarland, Pamela J Hooper, Sunny D Mante, Christopher Fitzpatrick, and Mark H Bradley. 2017. "Investment Success in Public Health: An Analysis of the Cost-Effectiveness and Cost-Benefit of the Global Programme to Eliminate Lymphatic Filariasis." *Clinical Infectious Diseases* ® 728 (6): 728–63. https://doi.org/10.1093/cid/ciw835.

Turner, Hugo C, and Donald AP Bundy. 2020. "Programmatic Implications of the TUMIKIA Trial on Community-Wide Treatment for Soil-Transmitted Helminths: Further Health Economic Analyses Needed before a Change in Policy." *Parasites and Vectors* 12 (102). https://doi.org/10.1186/s13071-020-3977-7.

Turner, Hugo C, James E Truscott, TD Hollingsworth, Alison A Bettis, Simon J Brooker, and Roy M Anderson. 2015. "Cost and Cost-Effectiveness of Soil-Transmitted Helminth Treatment Programmes: Systematic Review and Research Needs." *Parasites and Vectors* 8 (355). https://doi.org/10.1186/s13071-015-0885-3.

Uniting to Combat NTDs. 2012. "London Declaration on Neglected Tropical Diseases." 2012. https://unitingtocombatntds.org/wp-content/uploads/2017/11/london_declaration_on_ntds.pdf.

———. 2016. "Executive Summary: Beating 10 Diseases, Reaching a Billion People." 2016. https://unitingtocombatntds.org/reports/5th-report/executive-summary/.

Valente, Thomas W., and Patchareeya Pumpuang. 2007. "Identifying Opinion Leaders to Promote

Behavior Change." *Health Education and Behavior* 34 (6): 881–96. https://doi.org/10.1177/1090198106297855.

Walsh, Julia A., and Kenneth S. Warren. 1979. "Selective Primary Health Care." *New England Journal of Medicine* 301 (18): 967–74. https://doi.org/10.1056/nejm197911013011804.

Warren, KS, DAP Bundy, RM Anderson, AR Davis, DA Henderson, and DT Jamison. 1993. "Helminth Infections." In *Disease Control Priorities in Developing Countries*, 1st Editio, 131–60. Oxford: Oxford University Press.

Watts, Charlotte. 2017. "Neglected Tropical Diseases: A DFID Perspective." *PLoS Neglected Tropical Diseases* 11 (4). https://doi.org/10.1371/journal.pntd.0005492.

Weiss, D. J., A. Nelson, C. A. Vargas-Ruiz, K. Gligorić, S. Bavadekar, E. Gabrilovich, A. Bertozzi-Villa, et al. 2020. "Global Maps of Travel Time to Healthcare Facilities." *Nature Medicine* 26 (12): 1835–38. https://doi.org/10.1038/s41591-020-1059-1.

Welch, Vivian A., Elizabeth Ghogomu, Alomgir Hossain, Shally Awasthi, Zulfi Bhutta, Chisa Cumberbatch, Robert Fletcher, et al. 2016. "Deworming and Adjuvant Interventions for Improving the Developmental Health and Well-being of Children in Low- and Middle-income Countries: A Systematic Review and Network Meta-analysis." *Campbell Systematic Reviews* 12 (1): 1–383. https://doi.org/10.4073/csr.2016.7.

WHA. 2011. "Resolution 54.19 Schistosomiasis and Soil-Transmitted Helminth Infections." Geneva, Switzerland.

WHO. n.d. "Soil-Transmitted Helminths: Number of Children (Pre-SAC and SAC) Requiring Preventive Chemotherapy for Soil-Transmitted Helminthiases: 2019." Accessed April 7, 2021. https://apps.who.int/neglected_diseases/ntddata/sth/sth.html.

———. 2004. "Intensified Control of Neglected Diseases Report of an International Workshop." Geneva. www.who.int.

———. 2006a. "Preventive in Human Helminthiasis Chemotherapy, Coordinated Use of Anthelmintic Drugs in Control Interventions: A Manual for Health Professionals and Programme Managers." Geneva, Switzerland.

———. 2006b. "Strategic and Technical Meeting on Intensified Control of Neglected Tropical Diseases." Geneva. http://www.who.int/neglected_diseases/en/.

———. 2011. "Helminth Control in School-Age Children: A Guide for Managers of Control Programmes, Second Edition." Geneva, Switzerland. http://www.who.int/neglected_diseases/en.

———. 2012. "Accelerating Work to Overcome the Global Impact of Neglected Tropical Diseases: A Roadmap for Implementation." Geneva, Switzerland.

———. 2016. "Coverage Evaluation Surveys for Preventive Chemotherapy: Field Guide for Implementation." Geneva, Switzerland. http://www.who.int/about/licensing/copyright_form/en/index.html.

———. 2017. *Preventive Chemotherapy to Control Soil-Transmitted Helminth Infections in at-Risk Population Groups*. Geneva, Switzerland: WHO. http://apps.who.int/bookorders.

———. 2020a. "COVID-19: WHO Issues Interim Guidance for Implementation of NTD Programmes." WHO. World Health Organization. 2020. http://www.who.int/neglected_diseases/news/COVID19-WHO-interim-guidance-implementation-NTD-programmes/en/.

———. 2020b. *Ending the Neglect to Attain the Sustainable Development Goals*. Geneva, Switzerland: World Health Organization. https://doi.org/10.1596/978-1-4648-0524-0/ch17.

———. 2021. "A Sustainability Framework for Action against Neglected Tropical Diseases 2021–2030. Ending the Neglect to Attain the Sustainable Development Goals." Geneva, Switzerland. https://www.who.int/publications/i/item/9789240019027.

WHO, and WHO Expert Committee on the Control of Schistosomiasis. 2002. "Prevention and Control of Schistosomiasis and Soil-Transmitted Helminthiasis: Report of a WHO Expert Committee." Geneva, Switzerland. https://apps.who.int/iris/handle/10665/42588.

World Bank. n.d. "World Bank Indicators." https://data.worldbank.org/indicator.

———. 1993. *World Development Report 1993: Investing in Health*. *World Development Report 1993*. New York: Oxford University Press. https://doi.org/10.1596/0-1952-0890-0.