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CDEP-CGEG WP No. 87

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June 2020

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The cost-benefit and cost-effectiveness of providing menstrual cups and sanitary pads to schoolgirls in rural Kenya

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Abstract

Objective: To analyze the relative value of providing menstrual cups and sanitary pads to schoolgirls in rural Kenya.

Methods: From a healthcare payer or government program perspective, program costs were calculated for two interventions (provision of menstrual cups or sanitary pads) to girls (14-16 years old) in Kenya for one year. Cost-effectiveness analyses were conducted based on the health effects – in terms of reductions in disability-adjusted life years (DALYs) – and education effects – in terms of reductions in school absenteeism – of both interventions reported in a randomized controlled feasibility study. The health and education benefits were summed and compared to overall program costs.

Results: The cost of menstrual cups is estimated at $2,730 per year for 1000 girls, compared to $22,420 for sanitary pads. The benefit of the menstrual cup program (1.4 DALYs averted, valued at $7,000) is higher than that of a sanitary pad program (0.48 DALYs averted, valued at $2400).

However, the health effects of both interventions are not statistically significant, likely due to the limited power of the feasibility study. The menstrual cup intervention may be cost-effective in improving health outcomes ($2,000/DALY averted). The sanitary pad intervention has a cost-effectiveness of $280/student-school year in reducing school absenteeism. Meanwhile, combining health and education effects, the sanitary pad intervention is cost-saving with a net benefit of $92,000.

Conclusions: The menstrual cup may provide a cost-effective solution for menstrual hygiene management in low-income settings. Provisions of sanitary pads is a cost-saving policy when considering health and education benefits jointly. This study outlines a methodology for future CEA and CBA on menstrual hygiene interventions and highlights several methodological challenges that need to be addressed before other similar analyses can be robustly conducted.

Introduction

Adolescent girls around the world are at risk of sexual and reproductive health harms due to poor menstrual hygiene. Menstrual hygiene habits can impact incidence of sexually transmitted infections (STIs) and reproductive tract infections (RTIs), school attendance and performance, psycho-social health, and outcomes such as fear of leaking and shame, all of which can contribute to the inability of girls to reach their potential (Hennegan et al. 2019; Mason et al. 2013; Montgomery et al. 2016; Phillips-Howard et al. 2016; Sivakami et al. 2019; Sommer 2010; 2013; Tegegne and Sisay 2014; Schoep et al. 2019). Providing sanitary interventions, such as menstrual cups and sanitary pads, could mitigate these adverse effects.

Until recently, reusable menstrual cups have received little attention and have not been widely used in comparison with single-use products such as sanitary pads. Evidence indicates menstrual cups are a good option for menstrual hygiene management (MHM) (Eijk et al. 2019). However, no comprehensive economic analysis that could aid in financially motivating programs providing MHM products like menstrual cups has yet been undertaken. Cost-benefit (CB) and cost-effectiveness (CE) analyses can help put the issue of MHM on the international public health agenda and spur the scale-up of effective national and international policies.

We explore the costs and benefits associated with a randomized controlled feasibility study in Siaya County in western Kenya that targeted primary school girls. In the feasibility study, the interventions, which were randomly allocated at the school level, comprised of three treatment arms: (i) sanitary pads provided monthly, (ii) a menstrual cup (one cup, which can be reused up to 10 years), or (iii) control, where girls continued their usual menstrual care practices. Thirty schools (10 per intervention arm) participated in the study; from these schools, all girls who were 14-16 years old, who had experienced at least three menses, and who had no disability precluding their ability to participate were invited to participate. For ethical reasons, all students in the program, including the control group, received soap and menstrual hygiene training, and all schools received soap to put at their handwashing stations. However, no further investments were undertaken regarding latrine quality.

Several papers have been published on the intervention, the results of which will provide the backdrop for these CB and CE analyses. Further detail on the school sample and the latrine quality can be found in Alexander et al. (2018), program compliance and attrition in Phillips-Howard et al. (2016), safety of menstrual cups in Juma et al. (2017), adoption of the menstrual cup in van Eijk et al. (2018), and school absenteeism behavior and psychosocial wellbeing in Benshaul-Tolonen et al. (2019). To estimate program benefits, we use the estimated treatment effects from previously published studies or working papers, relying on Phillips-Howard et al. (2016) and Benshaul-Tolonen et al. (2019). The feasibility study was registered, ISRCTN17486946 and was funded by the UK Medical Research Institute, Department for International Development, and Wellcome Trust Global Health Trials.

The randomized feasibility study measured the effect of providing menstrual cups or sanitary pads on three STIs – chlamydia, gonorrhea, and trichomoniasis – and two RTIs – bacterial vaginosis (BV) and candidiasis (Phillips-Howard et al. 2016). In addition to causing acute symptomatic infections, these STIs and RTIs in females can result in long-term sequelae, including pelvic inflammatory disease (PID), ectopic pregnancy, and tubal infertility (European Centre for Disease Prevention and Control 2020) and can facilitate acquisition and transmission of HIV infection (Chesson and Pinkerton 2000; Kissinger 2015). BV prevalence is specifically greatest in women in sub-Saharan Africa, and those with BV have a greater risk of having HIV, chlamydia, gonorrhea, and PID (van de Wijgert and Jespers 2017). Therefore, the STIs and RTIs measured in the study impose a significant health burden not only due to their widespread prevalence but also due to their ability to result in serious long-term health effects. Furthermore, it has been shown that a significant portion of the disease burden due to chlamydia and gonorrhea is due to limited access to care and poor diagnostic tools (Aledort et al. 2006). Therefore, possible interventions, such as sanitary pads or menstrual cups, that can improve MHM and potentially reduce the incidence of such conditions will have significant health benefits.

We estimate the health benefits due to the provision of menstrual cups or sanitary pads in terms of disability-adjusted life years (DALYs) averted through the reported reductions in STIs and RTIs. The DALY is a measure of health burden commonly used in evaluating the benefits of health interventions in cost-effectiveness and cost-benefit analyses (Kahn et al. 2012; Marseille et al. 2014). Subsequently, to monetarily value the disease burden, we value the DALYs averted using a willingness-to-pay (WTP) approach (R. T. Edwards and McIntosh 2019; McIntosh et al. 2010; Brent 2014).

Secondly, using the impacts of the randomized controlled feasibility study interventions on school attendance and performance reported in Benshaul-Tolonen et al. (2019), we calculate the cost-effectiveness of menstrual cups or sanitary pads in increasing schooling by reducing absenteeism. Drawing from the methodology of an analogous RCT that tested the effects of deworming on school-age children in Kenya (Miguel and Kremer 2004), we monetize the educational benefit of the menstrual cups and sanitary pads as the increase in the net present value of future wages as a result of improved school attendance and performance, and we compare this benefit to the program costs. Lastly, we consider the effects of the interventions on the psychosocial wellbeing of the secondary school girls and the differences in environmental waste produced between use of menstrual cups and sanitary pads.

Methods

Program costs to provide either menstrual cups or sanitary pads were estimated based on the feasibility study's costs. The improvements in health outcomes as a result of each intervention were quantified in terms of DALYs and valued using a WTP approach. Previously reported impacts on school attendance were also considered and valued using a HC approach. The cost-effectiveness of each intervention in improving health or education effects was calculated. Lastly, the valuations of the health and education effects were combined and compared to program costs.

Table 1: Factors to consider in CB and CE analysis of menstrual hygiene interventions

Costs	Outcomes
Material costs (cloth, pads, menstrual cup)	Sexually transmitted infections
Education and training	Reproductive tract infections
Soap and hygiene	School dropout
Maintenance (cleaning costs, including firewood)	School absenteeism
Environmental costs (disposal)	School performance
	Future wages and productivity
	Psychosocial effects

A. Program costs

Based on the program costs for the feasibility study (outlined in Table 1), the cost of the control group (provision of puberty education and soap in addition to usual practice of menstrual hygiene management) for 1,000 individuals for one year was calculated. Subsequently, we calculated the costs of a program providing menstrual cups or sanitary pads for 1,000 individuals for one year. Program costs were calculated from the perspective of a government program or healthcare payer providing these interventions, including the necessary logistics and personnel for such a program (McIntosh et al. 2010). Research administrative costs were not included, making the costs align with potential future large scale programs. The cost of the two intervention groups relative to the control group was compared with the health and education benefits of each intervention relative to the control group. Costs were considered over a one-year period, so no time discounting was required. Lastly, for all currency conversions between Kenya Shilling (KES) and United States Dollar (USD), a conversion rate equating 1USD to 101KES was used, reflecting the exchange rate at the time of writing (XE.com Inc. 2019)[1].

The local bulk order prices were used for MHM products. For the remaining costs, unit costs were derived from the feasibility study. Sixteen sanitary pads (two packs) were estimated to be required per month, representing an upper bound estimate. Alternatively, one reusable silicone menstrual cup is predicted to last 10 years. Therefore, in calculating costs for a program providing menstrual cups to 1,000 individuals for one year, one-tenth of the cost for a menstrual

[1] The exchange rate has been relatively stable over the past year (1USD to 100-107KES).

cup was considered. It is possibly naïve to assume universal and perfect employment of a menstrual cup for 10 years[2]. Further, the menstrual cup may have to be replaced if lost; therefore, the menstrual cup replacement costs were calculated using the proportion of menstrual cups lost in the feasibility study (van Eijk et al. 2018).

B. Health effects

DALYs were used in this analysis to measure the effects of the interventions in decreasing disease burden, including both the initial infection and the future sequelae that may result from an acute infection. Zero DALYs indicates a year lived in perfect health, one indicates death, and an intermediate value is the equivalent of a year of life lived in less than perfect health (Murray 1994; Sassi 2006). To calculate DALYs, the years of life lost (YLL) and years lost to disease (YLD) were summed.

$$DALY = YLL + YLD = (N * R) + (I * D * L)$$

N is number of deaths, *R* the residual life expectancy at time of death, *I* the number of incident cases, *D* the disability weight for the condition, and *L* the average time until remission or death (Devleesschauwer et al. 2014a; Murray 1994). While more recent Global Burden of Disease (GBD) studies use a prevalence-based approach to calculate YLD, the incidence-based approach is still preferred to the prevalence-based approach specifically in studies considering infectious diseases (James et al. 2018; Mangen et al. 2013). Furthermore, calculations of DALYs in the GBD studies originally applied age-weighting and time-discounting functions, though GBD studies since 2010 have decided against the use of age-weighting or time-discounting (GBD 2013 DALYs and HALE Collaborators et al. 2015; Murray et al. 2012). Therefore, in this analysis, we do not apply either age-weighting or time-discounting. We assume a life expectancy of 86 years, consistent with GBD studies (Murray, Ezzati, et al. 2012).

In the feasibility study, the health effect of the MHM interventions was based on the reductions in the number of individuals who contracted specific acute infections – chlamydia,

[2] Menstrual cups come in different sizes, and the suitable size changes over the course of a woman's lifetime and with experiences of pregnancy and childbirth.

trichomoniasis, gonorrhea, bacterial vaginosis, and candidiasis (Phillips-Howard et al, 2016). However, each of the acute infections can transition to new and more long-term health states with different disability weights and durations and/or can increase the risk of acquiring other infections. This issue is likely to be more acute in contexts with limited access to diagnostic and curative health care and among more vulnerable populations, which could include sexually active adolescents. We follow the progression of health states that can potentially result from each pathogen in order to account for the overall disease burden associated with each prevented case of an infection (Devleesschauwer et al. 2014b; Mangen et al. 2013). This approach has been previously utilized in the Burden of Communicable Diseases in Europe (BCoDE) project by the European Center for Disease Prevention and Control (Colzani et al. 2017) and a related study on the infectious disease burden in the Netherlands (Bijkerk et al. 2014; Kretzschmar et al. 2012; Mangen et al. 2013; van Lier et al. 2016).

The pathogen-based Markov disease models, including transition probabilities between and durations of health states, for chlamydia and gonorrhea were adopted from the most updated BCoDE toolkit (European Centre for Disease Prevention and Control 2020). The most updated GBD disability weights for each sequelae were substituted into the disease models in place of disability weights used in the BCoDE, which were elicited from a European population (James et al. 2018). For trichomoniasis, bacterial vaginosis, and candidiasis, no validated disease model outlining all long-term sequelae, transition probabilities, and durations could be found. Therefore, DALYs per trichomoniasis, bacterial vaginosis, and candidiasis case were estimated by considering those infections' resultant increase in the risk of chlamydia (Brotman et al. 2010), gonorrhea (Brotman et al. 2010), and HIV (Mavedzenge et al. 2010; van de Wijgert et al. 2008). However this method still overlooks other potential negative effects, such as pregnancy and birth outcomes (Dingens et al. 2016) or effects on HIV transmission (Cohen et al. 2012)[3]. The baseline risk of chlamydia and gonorrhea in this population was estimated by prevalence of each outcome in control group of RCT (Phillips-Howard et al. 2016); baseline risk of HIV in this sample was estimated by incidence of HIV in Kenya in the population aged 15-49 (National AIDS Control Council 2018). While an incidence rate more specific to the study sample would have been

[3] The DALY estimates for trichomoniasis, bacterial vaginosis, and candidiasis also do not include the burden of the initial acute infections, which are negligible compared to the current estimate and do not have clear parameters in the existing literature.

preferred, especially due to the higher risk of HIV among female adolescents compared to male adolescents (Dupas 2011), this data could not be identified. Full details of health effects calculation for all five outcomes are included in the Supplementary Information.

The intervention in this feasibility study only resulted in statistically significant reduction in incidence for chlamydia. However, since there were some marginally significant health outcomes due to study's limited power, the prevalence ratios and confidence intervals for all five health outcomes were considered, and the DALYs for all health outcomes were summed. Additionally, the median length of follow-up of study participants in the feasibility study was 10.9 months (Phillips-Howard et al. 2016). Due to the lack of statistical power when limiting the analysis to participants with 12 months of follow-up, the prevalence of health outcomes including all participants was extrapolated to 12 months of intervention, assuming a linear relationship between intervention duration and incidence.

To conduct a cost-effectiveness analysis, the total cost of an intervention program providing either menstrual cups or sanitary pads to 1,000 individuals for one year was considered relative to the cost of the control group. To find the cost per DALY averted, the relative cost was divided by the number of DALYs that would be averted through such a program. Further, to evaluate the cost-effectiveness of the intervention, we compared cost-effectiveness to the threshold suggested by WHO. Based on the 2001 Report of the Commission on Macroeconomics and Health, a health intervention that averts one DALY at a cost up to three times the national GDP per capita is suggested to be cost-effective (World Health Organization Commission on Macroeconomics and Health 2001), and very cost effective if the cost is below the national GDP per capita. The GDP per capita for Kenya in 2017 was $1,595 (current USD) (World Bank 2017).

Furthermore, in order to conduct a cost-benefit analysis, DALYs were valued monetarily using a willingness-to-pay (WTP) approach (R. T. Edwards and McIntosh 2019; McIntosh et al. 2010; Brent 2014). While a willingness-to-pay (WTP) approach theoretically includes all three categories of health benefits (direct savings from averted healthcare expenditures, indirect savings from restored earnings, and intangible savings from averted pain and suffering), a human capital (HC) approach only considers the indirect benefits of an intervention (Brent 2014).

Therefore, to value the averted DALYs in monetary terms, we used a WTP method previously described by Hirth et al. (2000) to value a QALY. To estimate the value of an averted DALY, the value of a statistical life (VSL) was divided by the average residual life expectancy of the population for whom the VSL was estimated. The VSL used for Kenya was $230,000. This VSL was estimated by Viscusi and Masterman (2017) by using a base US VSL of $9.6 million and then adjusting that value using the relative GNI and income elasticity in Kenya.

As a result of the diversity of the approaches for calculating DALYs (application of age weighting and time discounting), the differences in expert judgments on the threshold value for the effectiveness of an intervention, and the different approaches used in valuing interventions (human capital approach and willingness-to-pay approach), there is no standard valuation method for a DALY. Previous valuations range anywhere from two-fifths to five times the GDP per capita for a single DALY (C. Edwards 2011). Therefore, such an intervention may still be beneficial for the target population regardless of the estimates here.

C. Education effects

Providing menstrual cups or sanitary pads to school-age girls had no statistically significant effect on school dropout rates (Phillips-Howard et al. 2016). In addition, providing menstrual cups had no effect school absenteeism; however, sanitary pads led to a 7.9% reduction in absenteeism (Benshaul-Tolonen et al. 2019). A program providing sanitary pads to 1,000 school-age girls for a one-year duration leads to an increase in attendance of 79 student-school years. To evaluate the cost-effectiveness of sanitary pads as a means to improve school attendance, the relative cost of a program providing sanitary pads to 1,000 school-age girls for one year was divided by the increase in years of schooling across the same population as a result of the intervention. The cost-effectiveness of menstrual cups as an intervention was not calculated given that there was no statistically significant impact on attendance reported.

The human capital (HC) approach was adopted to monetize the benefit of an increase in school attendance, similar to Miguel and Kremer (2004). The rate of return to education in Kenya is estimated at 17% (16% return for females receiving education at a primary level, 18% return for individuals at primary level in rural environments (Peter 2014), and earlier estimates places it at

17% (Knight and Sabot, 1990). That rate of return is decomposed to a 7% return on each additional year of primary school (Miguel and Kremer 2004). Consistent with Miguel and Kremer (2004) methodology, we assume that each individual will earn wages for 40 years and that wages are 60% of the output per worker. To calculate the net present value of the increase in future wages, a discount rate of 5% is applied.

D. Cost-benefit analysis

The monetized valuations of the education effects were added onto the valuations of the health effects to calculate the total benefit of each intervention. This total benefit was then compared to the relative cost of each intervention. Even though the reductions in infections were monetized using a WTP approach, which theoretically accounts for all effects arising from improvements in health, the decrease in school absenteeism was assumed to be a result of a separate mechanism than the reduction in infections, namely improvements in psychosocial well-being. This is motivated by the relatively low prevalence of infections in the population compared to the common narrative of fears surrounding the social stigmas attached to menstruation found in qualitative studies (Sivakami et al. 2019; Mason et al. 2013; Sommer 2010). We argue that improvements in psychosocial well-being – such as mitigating the fear of leaking, smelling, or social stigma – of the individuals resulted in decreased absenteeism, rather than the reduction in infections.

E. Environmental effects

The environmental cost of providing menstrual cups is the production of one cup per 10 years that is put in waste (and potentially some cleaning costs, such as firewood). The environmental footprint of single-use sanitary pads is assumed to be measurably larger than that of menstrual cups because a woman may use as many as 2,080 pads over the course of 10 years, assuming 16 pads per menstrual cycle and 13 menstrual cycles (of 28 days) per year. It has been estimated that a menstrual cup leads to 0.01kg of waste is per person per year (Weir 2015) compared to 1.3-2.7kg of waste when sanitary pads are used (Eijk et al. 2019). Additionally, disposing of used sanitary pads can cause psychological stress if disposal mechanisms are lacking, a concern expressed by one student in the pre-intervention focus groups (Mason et al., 2013) as well as lead to environmental contamination or high pressure on latrines where improperly discarded pads can clog sanitation systems or quickly fill the available pits.

There are costs associated with keeping a menstrual cup clean. A menstrual cup may be used for the duration of the menstrual period and cleaned by being boiled in water and dried at the end. Users need to wash their hands with soap prior to handling the menstrual cup, such as during insertion and emptying of the cup. We consider soap and boiling costs as private economic costs and exclude them from the program costs. Additionally, there are the environmental costs associated with the use of cloth, the most commonly used menstrual hygiene product according to focus group discussions (Mason et al., 2013). Cloths need to be regularly washed and are larger in volume, so resource use is likely higher than for a menstrual cup. Psychological costs associated with drying menstrual cloths in the open because of stigma are not considered here (Mason et al., 2013). Therefore, we assume that the environmental burden for menstrual cups, sanitary pads and cloths, is the smallest for the menstrual cup.

F. Psychosocial wellbeing

MHM interventions can affect psychosocial wellbeing by making period management in school and outside of school easier through reduced fear of leaking and smelling, and reduce shame from observable acts such as cleaning, drying and disposing of materials. In addition to the educational effects, Benshaul-Tolonen et al. (2019) discuss the implications that the program had on psychosocial wellbeing by using the PedsQL 23 multifaceted indicators that capture physical, emotional, social and school functioning. The program had positive, statistically significant effects on physical wellbeing and improvements in other dimensions for subgroups, depending on their menstrual cycle characteristics. We are not monetizing these effects because of lack of mapping from the effect to DALYs or to educational outcomes.

Results

A. Program costs

Based on the perspective of a government/healthcare program, the annual program costs for the baseline scenario, including puberty education, disposal of usual practice MHM method, and soap, was 4.19 USD per student (Table 2). In comparison, the annual program costs for the provision of menstrual cups and sanitary pads were 6.92 USD and 26.61 USD, respectively (Tables 3 and 4). Private and environmental costs were not considered. Relative to the control group, provision of menstrual cups costs 2.73 USD annually per student, and provision of sanitary pads costs 22.42 USD annually per student (Table 5).

Table 2: Costs for control group in the feasibility study. Girls were provided puberty education and soap but allowed to continue their usual MHM practice[4].

Control Group		
Item	*Annual cost per student (USD)*	*Notes/assumptions*
Disposal	0.34	Based on average costs of pad disposal during feasibility study
Soap for hygiene	1.50	1 soap required per term; total 3 terms per year
Training for nurses	0.58	3 hours of training required
Training for girls, puberty education	0.77	2 hours of class training plus travel time; 22 students on average per class
Training materials, puberty education	1.00	
TOTAL	**4.19**	
Private costs	*Annual cost per student (USD)*	*Privately borne costs are not considered in the program costs.*
Usual practice	Varying	Dependent on usual practice
Firewood/water	Varying	Dependent on usual practice. Cloths should be washed regularly to be kept clean.

[4] We value the cost of usual practice at 0 USD, acknowledging that there are private costs to usual practice.

Table 3: Costs for a potential program providing menstrual cups for 1000 individuals for one year.

Intervention Group – Menstrual Cups		
Item	*Annual cost per student (USD)*	*Notes/assumptions*
Menstrual cups	0.80*	Total cost 8USD; single cup lasts 10 years *8USD was the price to acquire menstrual cups in this study; the actual cost of the cups is 10USD. However, sensitivity analyses using the higher cost do not change study conclusions.
Replacement for lost menstrual cups	0.05	6.3% of students lost their menstrual cups (van Eijk et al. 2018)
Soap for hygiene	1.50	1 soap required per term; total 3 terms per year
Training for nurses	0.58	3 hours of training required
Repeat training for students by nurses	1.53	Two half-day class repeat trainings required annually; 22 students on average per class
Training for girls, puberty education	0.77	2 hours of class training plus travel time; 22 students on average per class
Training materials, puberty education	1.00	
Training for girls, menstrual cup usage	0.19	1 hour of class training in addition to puberty education
Training materials, menstrual cup usage	0.5	
TOTAL	**6.92**	
Private costs	*Annual cost per student (USD)*	*Privately borne costs are not considered in the program costs.*
Firewood	0.15	Firewood for heating water to boil the menstrual cup once per cycle.
Water	0.37	Water to boil the menstrual cup once per cycle

Table 4: Costs for a potential program providing sanitary pads for 1000 individuals for one year.

Intervention Group – Sanitary Pads		
Item	*Annual cost per individual (USD)*	*Notes*
Sanitary pads	24	1USD/pack; 2packs/month
Disposal	0.34	Based on average costs during feasibility study
Soap for hygiene	1.50	
Training for nurses	0.58	3 hours of training required
Training for girls, puberty education	0.77	2 hours of class training plus travel time; 22 students on average per class
Training materials, puberty education	1.00	
TOTAL	**26.61**	
Private costs	*Annual cost per student (USD)*	*Privately borne costs are not considered in the program costs.*
-	**-**	No private costs identified

Table 5: Relative costs for a program providing menstrual cups or sanitary pads[5].

Cost Comparison		
Comparison	Cost per individual (USD)	Cost per 1000 individuals (USD)
Menstrual cups vs control	2.73	2,730
Sanitary pads vs control	22.42	22,420

B. Health effects

In the pilot feasibility study, the interventions of providing menstrual cups or sanitary pads had a statistically significant effect on reducing the risk for chlamydia. However, since there were multiple marginally significant health outcomes and limited statistical power in the feasibility study, the prevalence ratios and confidence intervals for all five health outcomes were considered to calculate the total health benefit, and the DALYs for all health outcomes were summed.

[5] Relative cost calculated by subtracting cost of control group from cost of treatment group.

Prevalence of each infection was linearly extrapolated to a study period of 12 months (Table 6, column 3). Utilizing the pathogen-based disease model, transition probabilities, and health state durations for chlamydia and gonorrhea suggested by the BCoDE (European Centre for Disease Prevention and Control 2020) through a review of epidemiological literature as well as the most updated GBD disability weights (James et al. 2018), the total DALYs per infection (symptomatic or asymptomatic) of chlamydia and gonorrhea were calculated to be 0.0081 and 0.033 years, respectively (Table 7, column 2). This calculation encapsulates the long-term sequelae that can result from these infections. For trichomoniasis, bacterial vaginosis, and candidiasis infections, the DALYs averted per prevented infection was calculated considering the effect of each infection on the subsequent risk of contracting chlamydia[6], gonorrhea, and HIV. DALYs per case of trichomoniasis was 0.012 years, bacterial vaginosis was 0.011 years, and candidiasis was 0.011 years (Table 7, column 2) (calculations detailed in Supplementary Information).

Considering the baseline prevalence of each infection in the control group and the prevalence ratio of infections in the treatment groups (Table 6), the reductions in each infection and DALYs averted were calculated for a potential program providing menstrual cups or sanitary pads to 1000 individuals for one year (Table 7, column 3-4). For a program providing menstrual cups, the greatest reduction in infections and DALYs averted was for bacterial vaginosis, 65 fewer infections per 1000 individuals provided intervention and 0.75 DALYS averted. For a program providing sanitary pads, the greatest effect was for chlamydia, 33 fewer infections per 1000 individuals provided intervention and 0.27 DALYs averted. These estimates do not consider the long-run reduction in infection rates among non-study participants (externalities); averted infections in the target population reduce transmissions and, hence, downstream cases.

Cost-effectiveness analysis of health effects

Considering that the relative cost of providing menstrual cups to 1,000 participants in Kenya for one year would be $2,730 (Table 5) and that such a program would result in 1.4 DALYs averted (95% CI: -4.3, 3.1) (Table 7, column 4), the point estimate for the cost-effectiveness of this

[6] Though reductions in chlamydia and gonorrhea measured within the program are also included in the calculations, the risk of overestimating the benefits is minimal since we used the hazard ratio of developing chlamydia or gonorrhea at a time point subsequent, not simultaneous, to the original bacterial vaginosis infection. Therefore, there is limited overlap with incident chlamydia or gonorrhea cases already captured in the feasibility study.

intervention for reducing infection is $2,000 per DALY averted (Table 9). Analogously, the cost of providing sanitary pads to 1,000 school-age girls in Kenya would be $22,420 (Table 5), and such a program would result in 0.48 DALYs averted (95% CI: -4.2, 2.3) (Table 7, column 4). The cost-effectiveness of this intervention for reducing infection is $47,000 per DALY averted (Table 9). GDP per capita in Kenya is $1,595, and the WHO's Commission on Macroeconomics and Health suggests that an intervention is cost-effective up to a value three times GDP per capita, $4,785 in Kenya. Thus a menstrual cup program would cost only 42% of WHO's recommended value, suggesting that it may be cost-effective. A sanitary pad program would cost 14-fold higher. However, there are multiple limitations to this analysis discussed later.

Valuation of health effects

The value of a DALY in Kenya was estimated using the willingness-to-pay approach explained in Brent (2014). Given that Viscusi and Masterman (2017) estimate a VSL of $230,000 in Kenya, the median age in Kenya is 20 years (Central Intelligence Agency 2018), and the life expectancy is 67 years (World Bank, 2017), 47 DALYs are valued at $230,000 in Kenya. Therefore, each DALY is $4,900. Given that provision of menstrual cups to school-age girls was calculated to result in 1.4 DALYs averted per 1,000 individuals treated, the benefit of the health effects would be $7,000 per year (95% CI: -$21000, $15000) (Table 7, column 5). A similar program providing sanitary pads to school-age girls would result in 0.48 DALYs averted per 1,000 individuals treated, valued at $2,400 per year (95% CI: -$21000, $1100) (Table 7, column 5). While the menstrual cup seems to improve health outcomes more than the sanitary pad, the health effects of both interventions are not statistically significant, likely due to the limited power of the feasibility study.

Table 6: Health endpoints by intervention group. Prevalence extrapolated to 12 months of intervention.

(1) Pathogen (infection)	(2) Intervention group	(3) Scaled prevalence of infection	(4) Prevalence ratio[1] (95% CI)	(5) P-value[1]
C. trachomatis (chlamydia)	cups	2.3%	0.46 (0.14, 1.49)	.195
	pads	1.6%	0.33 (0.12, 0.86)	.024
	control	5.0%		
T. vaginalis (trichomoniasis)	cups	1.8%	0.36 (0.11, 1.28)	.115
	pads	2.5%	0.65 (0.21, 2.02)	.457
	control	5.0%		
N. gonorrhea (gonorrhea)	cups	0.71%	1.07 (0.10, 11.56)	.956
	pads	0.51%	0.77 (0.08, 7.24)	.816
	control	0.66%		
Bacterial vaginosis	cups	16%	0.71 (0.47, 1.08)	.110
	pads	22%	0.97 (0.65, 1.44)	.864
	control	23%		
C. albicans (candidiasis)	cups	8.4%	0.92 (0.35, 2.43)	.871
	pads	10%	1.14 (0.61, 2.13)	.682
	control	9.1%		

[1]Adopted from Phillips-Howard et al, 2016.

Table 7: Health effects and value of reductions in infections due to MHM intervention.

(1) Pathogen (infection)	(2) DALYs/ infection[1]	(3) Reductions in infections/ 1000 provided intervention[2]		(4) DALYs averted/ 1000 provided intervention		(5) Valuation of DALYs averted/ 1000 provided intervention	
		Cups vs control	**Pads vs control**	**Cups vs control**	**Pads vs control**	**Cups vs control**	**Pads vs control**
C. trachomatis (chlamydia)	0.0081	27 (-24, 43)	33 (6.9, 44)	0.22 (-0.20, 0.34)	0.27 (0.056, 0.35)	$1100 (-$960, $1700)	$1300 ($270, $1700)
T. vaginalis (trichomoniasis)	0.012[3]	32 (-14, 44)	17 (-51, 39)	0.40 (-0.17, 0.55)	0.22 (-0.63, 0.49)	$1900 (-$850, $2700)	$1100 (-$3100, $2400)
N. gonorrhea (gonorrhea)	0.033	-0.46 (-70, 5.9)	1.5 (-41, 6.1)	-0.015 (-2.3, 0.20)	0.051 (-1.4, 0.20)	-$76 (-$11000, $970)	$250 (-$6700, $990)
Bacterial vaginosis	0.011[3]	65 (-18, 120)	6.8 (-99, 79)	0.75 (-0.21, 1.4)	0.077 (-1.1, 0.90)	$3700 (-$1000, $6700)	$380 (-$5600, $4400)
C. albicans (candidiasis)	0.011[3]	7.3 (-130, 59)	-13 (-100, 36)	0.079 (-1.4, 0.64)	-0.14 (-1.1, 0.39)	$390 (-$6900, $3100)	-$680 (-$5500, $1900)
TOTAL				**1.4 (-4.3, 3.1)**	**0.48 (-4.2, 2.3)**	**$7000 (-$21000, $15000)**	**$2400 (-$21000, $11000)**

Values in parentheses include 95% confidence intervals. Dark green cells are significant at 95%.

[1]Infection refers to both symptomatic and asymptomatic infections.

[2]Calculated using prevalence ratios from Table 1.

[3]The DALYs/infection for *T. vaginalis*, bacterial vaginosis and *C. albicans* only consider the increased risk of contracting chlamydia, gonorrhea, and/or HIV as a result of the initial infection. This is in contrast to C. trachomatis and N. gonorrhea that include all potential long term effects of the infections.

C. Education effects

Cost-effectiveness analysis

Given relative program costs of $22,420 (Table 5) to provide sanitary pads to 1000 school-age girls for one year and the expected increase of 79 student-school year equivalents as a result of such a program (Benshaul-Tolonen et al. 2019), the cost-effectiveness of a sanitary pad intervention is estimated to be $280/student-school year (Table 9). However, provision of sanitary pads is more cost-effective than many previous trials providing subsidies and cash transfers to improve attendance (J-PAL Policy Bulletin 2017). The cost-effectiveness of menstrual cups in improving school attendance was not calculated since Benshaul-Tolonen (2019) did not report statistically significant improvements in attendance in the treatment group receiving that intervention.

Valuation of education effects

Assuming no wage growth and wages as 60% of GDP per capita, the annual wage of an individual in Kenya is $957. Using a 7% return for each additional year of schooling, the result of the average 0.079 years of schooling per individual gained with the sanitary pad intervention is a $5 increase in the annual wage to $962 per year (Table 8, column 2). As calculated according to the human capital approach, the increase in the net present value (NPV) of wages over the course of 40 years (discounted 5% annually) as a result of one-year provision of sanitary pads is, on average, $92 per individual (Table 8, column 4). Therefore, the monetized benefit of a program providing sanitary pads to 1,000 school-age girls for one year is $92,000.

Table 8: Effect of sanitary pad program on earnings as a result of decreased absenteeism.

(1) Group	(2) Annual wage (per individual)	(3) Total wages over 40 years (per individual), discounted at 5% per year	(4) Difference in NPV of wages (per individual)
No intervention	$957	$16,680	+$92
Sanitary pad intervention	$962	$16,773	

C. Cost-benefit analysis

Given that there were no measured education effects, in terms of reduced absenteeism, for providing menstrual cups, the total benefit of a program providing menstrual cups for 1,000 individuals for one year was estimated to be $7000 (95% CI: -$21000, $15000), and the total relative cost of the program was estimated to be $2,730. Therefore, the net benefit would be $4270 (95% CI: -$23730, $12270) (Table 9). Whether this intervention is cost-saving is unclear, primarily due to the limited power of the feasibility study. A larger study is needed to clarify these results.

Considering both the health and education effects, a program providing sanitary pads to 1,000 individuals for one year will have an estimated benefit of $94400 ($71000, $103000), with almost all arising from the increase in schooling (reduced absenteeism). Factoring in the relative program costs of $22420, such a program would have a net benefit of $71980 ($48580, $80580) and would be cost saving (Table 9). However, there are multiple issues that complicate both calculations, and they are discussed later.

Table 9: Summary of costs and benefits (USD) of providing menstrual cups or sanitary pads to 1,000 school-age girls for one year.

	Relative program cost	Health effects			Education effects		Combined
		DALYs averted	CEA (USD/DALY averted)	Valuation of averted DALYs (using WTP approach)	CEA (USD/student-school year)	Valuation of increased student-school years (using HC approach)	CBA
Menstrual cups program (1000 ind.)	$2,730	1.4 (-4.3, 3.1)	$2000/DALY averted	$7000 (-$21000, $15000)	*No significant effects of menstrual cup provision on absenteeism*	*No significant effects of menstrual cup provision on absenteeism*	Benefits: $7000 (-$21000, $15000) **Net: +$4270 (-$23730, $12270)**
Sanitary pads program (1000 ind.)	$22,420	0.48 (-4.2, 2.3)	$47000/DALY averted	$2400 (-$21000, $11000)	$280/student-school year	$92,000	Benefits: $94400 ($71000, $103000) **Net: +$71980 ($48580, $80580)**

Discussion

Review of main findings

The program costs of providing menstrual cups are significantly lower than the costs of providing sanitary pads: the cost of menstrual cups is estimated at $2,730 per year for 1000 girls, compared to $22,420 for sanitary pads. The health impacts of the menstrual cup program, in terms of DALYs averted due to reductions in STIs and RTIs, were greater compared to the health effects of the sanitary pad program (menstrual cup program: 1.4 DALYs averted, valued at $7000; sanitary pad program: 0.48 DALYs averted, valued at $2400). The health benefits of both interventions, however, are not statistically significant, likely due to the limited power of the feasibility study; we encourage future more well-powered research to confirm more precise effect sizes. However, using the point estimates for the health benefits, the cost-effectiveness of menstrual cups was $2000 per DALY averted compared to $47000 per DALY for sanitary pads, suggesting that menstrual cups may be cost-effective compared to commonly used thresholds. Menstrual cups still appear to be less cost-effective than deworming treatment, which has an estimated cost of $5/DALY (Miguel and Kremer 2004). However, 76% of the DALY reduction from deworming treatment was due to the externality benefits of school-wide deworming treatment, and such externalities were not measured in our randomized controlled feasibility study. In contrast, menstrual cups appear to be similar in cost-effectiveness to interventions for children focused on constructing piped water supply and sewer connections to improve sanitation, distributing cholera and typhoid vaccines, and treating obstructed labor with Caesarean delivery (Horton et al. 2017).

Lastly, considering the effects of the interventions on improving school attendance, the cost-effectiveness of the sanitary pad intervention would be $280/student-school year, while we estimate no positive impact on the menstrual cup treatment arm. For comparison, the cost-effectiveness of a mass deworming campaign is estimated to be $3.50/additional year of school participation (Miguel and Kremer 2004). Adding the education effects of the sanitary pad intervention to the health effects indicates that such a program would be cost-saving[7].

[7] While menstrual cups may be cost-effective in improving health outcomes, sanitary pads are cost-saving. This is due to the significant effect of sanitary pads on school absenteeism, which menstrual cups do not show. When the education effects are valued and summed with the health benefits, sanitary pads are cost-saving.

Limitations

We note several important methodological limitations. Importantly, the cost and benefit analyses are based on previously published results from a pilot study, and future studies must increase the reliability of the effect sizes that form the basis for this analysis. Currently, there are numerous challenges in calculating the total DALYs averted as a result of the two interventions in the feasibility study. First, improving MHM has multiple health effects. In this study, five STIs and RTIs were tracked. Therefore, it is possible that there were health effects that were not accounted for in the study.

Second, we could not identify any disease progression models for trichomoniasis, bacterial vaginosis, and candidiasis, which resulted in us not being able to calculate the DALYs averted due to all potential future sequelae for those infections. Instead we only consider the increased risks for contracting other infections as a way to include a portion of the longer-term health impact of these three conditions; regardless, the longer-term health impact of these outcomes will be underestimated in our analysis. For example, BV has been associated with an increased risk of HIV, chlamydia, gonorrhea, and (van de Wijgert and Jespers 2017; van de Wijgert et al. 2009; Bautista et al. 2016). For instance, a study among HIV-uninfected women in Zimbabwe and Uganda found that 17% of new HIV cases were attributable to BV (van de Wijgert et al. 2009). Furthermore, BV has shown to increase the risk of female-to-male HIV transmission (Cohen et al. 2012).

Third, the transition probabilities between health states and the duration of each health state were taken from a European model (BCoDE) since a comprehensive study providing transition probabilities and durations in rural Kenya was not found. Therefore, it is likely that the DALY parameters (based mostly on European populations) are underestimating the benefits of infections averted due to differences in access to prognosis and curative health care, as well as screening, for example during pregnancy, between the European and Kenyan populations. The following calculations must be interpreted acknowledging the differences in the environments between the European model and this current analysis and the potential effect on parameters used. A study published in *Nature* in 2006 finds that STIs, such as chlamydia, have high costs in terms of morbidity and mortality in developing countries with low access to diagnostic tools

(Aledort et al. 2006). More importantly, in this aforementioned disease burden calculation, the evaluation also considers transmission of STIs in a sexually active population and includes DALYs resulting from downstream cases of certain STIs. Considering a population of commercial sex workers in sub-Saharan Africa, the study calculates the DALYs saved from each treated gonorrhea and chlamydia case to be 5.08, which is significantly higher than our calculation and the BCoDE calculations. Using this DALY estimate in our evaluation, both menstrual cups and pads would be cost-effective at $23/DALY and $18/DALY, respectively, and cost-saving with net benefits of $590,000 and $720,000, when considering solely the benefits from reductions in chlamydia.

Fourth, though we calculate program costs for one year in our analysis, individuals in the feasibility study were tracked for various durations – median 10.9 months (IQR 6.1-12.5 months) (Phillips-Howard et al. 2016). Individuals with greater than nine months follow-up showed significantly higher health benefits than those with less than nine months of follow-up. However, due to the small sample sizes in this feasibility study, we calculate the prevalence estimates with all study participants but linearly scale estimates to a hypothetical one year of intervention.

Furthermore, educational and psychosocial wellbeing improvements of the program are underestimated. A recent study of US women aged 15-45 years old found that the productivity loss while present at school or work during menstruation was up to seven times greater than the loss due to missing work or school (Schoep et al. 2019). This suggests that there is a significant educational benefit in addition to school absenteeism, which was measured previously (Benshaul-Tolonen et al. 2019) and valued in this study. Future studies should measure academic learning (as an indicator for productivity) and include such effects in the evaluation. Moreover, we did not place a value of improvements in PedsQL, despite measuring positive treatment effects on girls' physical functioning both in the menstrual cup and the sanitary pad group (Benshaul-Tolonen et al. 2019).

One limitation is pertaining to representativeness of the sample. The schools included in the study were not fully representative as they included 30 schools in the district that met a latrine per pupil ratio. Therefore, some schools with worse latrine availability were excluded, alongside a few schools that declined participation. Schools with worse baseline latrine conditions may be the schools in which such a program would have the largest benefits.

Furthermore, three main positive externalities were not included in either the health effects or education effects valuations. 1) Improved menstrual hygiene management is predicted to have positive externalities for the household members of the individuals treated as a result of improved household hygiene. However, this pilot study did not collect any data on household hygiene; therefore, this benefit is not evaluated here. 2) The health estimates do not consider the long-run reduction in infection rates among non-study participants (externalities) due to a lower infection rate in the population. 3) There is significantly lower waste produced when menstrual cups are used. This is a difference between the two interventions that is not included in the valuations. Moreover, because of lack of data on private costs, they are not fully considered within the program. We encourage future studies to better reflect externalities and private costs.

The menstrual cup adoption rate was slow over time, such that treatment effects may be significantly underestimated in the timeframe for which data was collected. Additionally, it is fair to assume less than universal uptake of the menstrual cup; while 96% of study participants verbally reported using the menstrual cup after 9 months of enrollment, a usage rate of 70.8% of menstrual cups was verified using observations to record discoloration over time (van Eijk et al. 2018). These less-than-perfect adoption rates are already considered in the estimation of the health and education benefits, as they rely on regression estimates so called intent-to-treat, considering the program effects of the individuals that received the menstrual cup regardless of whether they used them. Due to the limited study duration, if usage increases over time, after the end of the study, the analysis will underestimate the long-run benefits. Long-run adoption rates and treatment effects should be considered in future analyses.

Conclusions

Overall, though the statistical power of the feasibility study was limited, this analysis provides initial evidence that interventions to improve MHM may have substantial cost-effective benefits on health and education. First, this study finds that menstrual cups could be provided at a significantly lower cost than sanitary pads within the context of a menstrual health policy. The menstrual cup provides a safe (van Eijk, 2019), environmentally sustainable, and low-cost solution to menstrual hygiene management challenges faced by adolescent girls in developing countries. Evidence from this randomized controlled feasibility study in Kenya and from a pilot study in Nepal show high levels of adoption of the cup among adolescent girls over time (Phillips-Howard et al., 2016; Oster and Thornton, 2011) in line with meta-analysis results provided by van Eijk et al., (2019), highlighting its potential as an effective public health policy.

Three aspects must be considered when comparing the cost-effectiveness and cost-benefit of sanitary pads versus menstrual cups. First, both the sanitary pad treatment and the menstrual cup treatment led to health improvements, though these results need to be confirmed by larger studies. Second, the sanitary pad program had positive benefits on school attendance. We may, however, not be able to detect a treatment effect of the menstrual cup on school attendance given the delayed adoption of the menstrual cup and that menstruation-related absenteeism is rare. Third, the environmental footprint, while not monetized in the analysis, is substantially smaller for the reusable menstrual cup compared with sanitary pads. Further analysis should confirm – using a longer treatment period and a larger sample size – the benefits of the menstrual cup, which may be an economically, logistically and environmentally sustainable solution to adolescent girls' menstrual health needs. We note that reusable sanitary pads may be an economically and environmentally efficient alternative solution, but no evaluations on their health and education effects have been undertaken so far.

While we outline a methodology for future CEA and CBA on menstrual hygiene interventions, our study highlights several methodological challenges. While this study does not provide a definite conclusion, it does lay the framework for which future analyses of MHM evaluations and exposes the gaps in understanding that need to be addressed before other similar analyses can be robustly conducted.

Acknowledgements

This manuscript and underlying research papers were supported by the Medical Research Council/Department for International Development/Wellcome Trust Global Health Trials scheme (G1100677/1). Prof. Benshaul-Tolonen is thankful for support from the Barnard College

Presidential Award. The funders had no role in study design, data collection and analysis, decision to publish, or manuscript preparation. The authors thank Prof. Robert Brent for guidance on the cost-benefit analysis. The manuscript was reviewed and approved by the Kenya Medical Research Institute Director.

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Supplementary Information

I. Chlamydia (*C. trachomatis*) health impact calculation
Figure S1: Pathogen-based disease model for chlamydia.
Table S1: Inputs used in calculating DALYs per chlamydia infection and associated long-term sequelae.
Table S2: DALY calculation per chlamydia infection and associated long-term sequelae.

II. Gonorrhea (*N. gonorrhea*) health impact calculation
Figure S2: Pathogen-based disease model for gonorrhea.
Table S3: Inputs used in calculating DALYs per gonorrhea infection and associated long-term sequelae.
Table S4: DALY calculation per gonorrhea infection and associated long-term sequelae.

III. HIV health impact calculation (*for use in health impact calculation for other infections)
Figure S3: Pathogen-based disease model for HIV.
Table S5: Inputs used in calculating DALYs per HIV infection and associated long-term sequelae.
Table S6: DALY calculation per HIV infection and associated long-term sequelae.

IV. Bacterial vaginosis (BV) health impact calculation
Table S7: DALY calculation per bacterial vaginosis infection as a result of increased risk for other health states.

V. Trichomoniasis (*T. vaginalis*) health impact calculation
Table S8: DALY calculation per trichomoniasis infection as a result of increased risk for other health states.

VI. *C. albicans* infection health impact calculation
Table S9: DALY calculation per trichomoniasis infection as a result of increased risk for other health states.