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Cost-effectiveness of a mobile technology-enabled primary care intervention for cardiovascular disease risk management in rural Indonesia

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Key Messages:

- There are large service gaps across Indonesia meaning that only a third of Indonesians at risk of Cardiovascular diseases (CVD) receive appropriate preventative treatments. Digital health interventions offer a potentially low-cost option to assist in overcoming these service gaps yet there is limited evidence of their use or cost-effectiveness in Indonesia or low and middle-income nations more generally.
- We conducted a cost-effectiveness analysis of a complex, technology-enabled primary care intervention for the management of individuals at high-risk of CVD relative to usual care from the Indonesian health-system perspective using a Markov model populated with robust local data collected during a pragmatic trial in the rural area of Malang district, Indonesia.
- We found the intervention to be a cost-effective means to expand health care coverage to a rural Indonesian population. Relative to usual care, the intervention strengthened empowerment of community health workers to identify individuals at high-risk of CVD within this setting and facilitate appropriate preventative care.
- The research begins to fill an important gap in available evidence on the cost-effectiveness of digital health interventions in low- and middle-income nations and
provides decision-makers in the Indonesian context with robust economic evidence based on local data.

Word Count: 3,252

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Abstract

Cardiovascular diseases (CVD) are the leading cause of death in Indonesia and there are large disparities in access to recommended preventative treatments across the country, particularly in rural areas. Technology-enabled screening and management led by community health workers has been shown to be effective in better managing those at high-risk of CVD in a rural Indonesian population, however, the economic impacts of implementing such an intervention are unknown. We conducted a modelled cost-effectiveness analysis of the SMART health intervention in rural villages of Malang district, Indonesia from the payer perspective over a 10-year period. A Markov model was designed and populated with epidemiological and cost data collected in a recent quasi-randomised trial, with 9 health states representing differing risk for experiencing a major CVD event. Disability-Adjusted Life Years were estimated for the intervention and usual care using disability weights from the literature for major CVD events. Annual treatment costs for CVD treatment and prevention were $US83 under current care and $US144 for those receiving the intervention. The intervention had an incremental cost-effectiveness ratio of $4,288 per disability-adjusted life year averted and $3,681 per major CVD event avoided relative to usual care. One-way and probabilistic sensitivity analyses demonstrated that the results were robust to plausible variations in model parameters and that the intervention is highly likely to be considered cost-effective by decision makers across a range of potentially acceptable willingness to pay levels. Relative to current care, the intervention was a cost-effective means to improve the management of CVD in this rural Indonesian population. Further scale-up of the intervention offers the prospect of significant gains in population health and sustainable progress toward universal health coverage for the Indonesian population.
Introduction

Cardiovascular disease (CVD) is a leading cause of death, disability and ill-health across the world (Roth et al., 2017, Prabhakaran et al., 2018). In the lower-middle income nation of Indonesia, CVD is responsible for approximately one-third of all deaths (Mboi et al., 2018). Indonesia’s health system is characterised by the geographic spread of the country across thousands of islands and a high level of decentralisation that designates the provision of healthcare services, including primary health care to local district health agencies. There are known service gaps across the country, particularly in rural areas, and less than a third of Indonesians at risk of CVD receive appropriate preventative treatments (Maharani and Tampubolon, 2014, Laksono et al., 2019, Mahendradhata et al., 2017). The current national response to the growing burden of CVD centres on preventing and managing CVD through advocacy, health promotion and health system strengthening (Kementerian Kesehatan Republik Indonesia, 2015). The strategy includes significant investment into an e-health platform in an attempt to use technology to overcome service and access gaps and strengthen the nation’s primary health care system.

The SMARThealth Extend quasi-experimental study demonstrated the potential of a complex technology-enabled primary care intervention to leverage this platform to identify and provide care to people living with, and at high-risk of, CVD (Patel et al., 2019). The intervention enabled non-physician community health workers (kaders) to perform screening for CVD risk in a rural Indonesian population and provide individual risk information, management plans and decision aids to assist nurses and doctors decide on appropriate treatment for high-risk patients. Exposure to the intervention was associated with a significantly greater proportion of people on recommended treatments to prevent or manage CVD (57% vs 16%) and a significant reduction in systolic blood pressure (−8.3 mm Hg). While these results are promising, the long-term impact of implementing such an intervention on health and economic outcomes is unknown.

Economic evidence is vital to guide policy-makers looking to implement interventions at scale as it provides information on the relative costs and benefits of different program or intervention options to inform decisions on the most effective use of available resources. This study presents a modelled cost-effectiveness analysis of the SMARThealth Extend intervention relative to usual care in the rural Indonesian province of Malang using a specifically developed Markov model.

Methods

We conducted a modelled cost-effectiveness analysis from the perspective of the Indonesian government (health-system payer). A completed Consolidated Health Economic Evaluation Reporting Standards checklist is included in the Appendix (Husereau et al., 2013).

Study setting and intervention

The SMARThealth Extend study examined the impact of the SMARThealth intervention on CVD risk factors and their management (Patel et al., 2019). The study was a controlled quasi-experimental study conducted across four intervention and four control villages in the Malang district of East Java province, Indonesia between August 2016 and March 2018. Following a co-design process with local authorities, intervention villages were selected by the Malang District Health Agency to maximise feasibility and geographic diversity. Control villages were matched with an intervention village based on population size, rurality, predominant occupation of residents, distance from tobacco factories and numbers of community health workers (kaders). Figure 1 provides an overview of the intervention and
further details are available elsewhere (Patel et al., 2019). In brief, the intervention facilitated kaders, nurses and doctors to assess CVD risk using basic equipment and provided a decision support application on a tablet device. Kaders collected patient information using the application and could inform the individual of their risk status, provide lifestyle advice and refer high-risk individuals for further care. Doctors in primary care centres and those on monthly visits to village health centres and nurses at village health centres received tailored decision support around appropriate prescriptions for preventative medications based on the patient data collected through kader screening and during the consultation itself. Kaders in the villages could immediately access treatment plans via the SMARTHealth platform and reminded high-risk individuals to attend follow-up visits and to take regular medications. Collected data on pharmaceutical use between the two arms of the study were used to inform the model as described in Table 1 and reductions in CVD risk were estimated based on the reductions in systolic blood pressure found for high-risk individuals in the SMARTHealth Extend (adjusted mean difference, −8.3 mm Hg; 95% Confidence Interval: −10.1 to −6.6 mm Hg).

Cohort characteristics

Key population characteristics in the model reflect the data collected during the SMARTHealth Extend study including the age and gender structure of the adult population, presence of risk factors, history of CVD, those presently accessing services and pharmaceutical treatments (Table 1). In brief, during the study kaders screened all adults in study villages over the age of 40 years to identify individuals at high CVD risk. 22,365 adults were screened through the SMARTHealth Extend study, 6,579 who were identified as high-risk for CVD based on the meeting any of the criteria:

1. A previous confirmed diagnosis of CVD
2. Extreme blood pressure elevation (systolic blood pressure >160 mmHg or diastolic blood pressure >100 mmHg)
3. A 10-year predicted CVD risk ≥ 30%
4. A 10-year predicted CVD risk of 20-29% and a systolic blood pressure >140 mmHg

The average age of high-risk participants was 59 in control villages and 58.3 in intervention villages, while 61% of individuals were female and an average systolic blood pressure of 167 across all villages. Further details of the cohort have been published in the effectiveness study (Patel et al. 2019). The ten-year risk of experiencing a major CVD event (defined as a moderate to severe stroke or myocardial infarction) was estimated using algorithms based on the former World Health Organization/International Society of Hypertension “low information” risk charts tailored to the South-East Asian Region-B. Participants were assigned an average ten-year risk score of 0.35 if they were assessed as having a risk score between 30-40 or if they were found to be clinically-high risk and have a previous diagnosis of CVD, 0.3 if they had previously diagnosed CVD or were deemed clinically high-risk and 0.4 if they had a risk score equal or greater than 40 according to WHO/International Society of Hypertension risk charts (World Health Organization, 2019, Maharani et al., 2019). These ten-year estimates were used to derive annual point estimates to populate the model. The impact of these assumptions and model inputs on the results were tested in the sensitivity analyses described below.

Model Structure

A Markov model was developed using TreeAge Pro 2018 software. The model consists of 9 health states reflecting differing risks of experiencing a major CVD event (Figure 2 depicts a
simplified version of the model). The parameters of the model are outlined in Table 1. Population epidemiological, risk factor, sociodemographic information, intervention cost and effectiveness were taken from the SMARThealth Extend study (Patel et al., 2019, Maharani et al., 2019). Other parameter inputs and transition probabilities were taken from the published literature. The model was used to simulate CVD progression in a hypothetical population of 1 million individuals receiving the intervention and 1 million receiving usual care for a period of 10 years. It was assumed that the initial screening part of the intervention to identify high-risk individuals occurred only once at the start of the period. From the systolic blood pressure reductions observed in the SMARThealth Extend study, we modelled the numbers of major CVD events based on an assumption of a reduction in the risk of experiencing a CVD event of 20% for every 10mmHg reduction in systolic blood pressure, based on a recent systematic review and meta-analysis of randomised clinical trials (Ettehad et al., 2016). The death rate of those who experience CVD events was estimated using results from the literature for middle income nations. (Yusuf et al., 2014) The non-CVD related death rate was estimated using published estimates for a rural Indonesian population and WHO life tables (Rao et al., 2010, World Health Organization, 2020). Individuals could have multiple CVD events over the ten-year period.

Costs

Costs were assessed from a health service (payer) perspective. Costs associated with intervention delivery (including personnel, equipment, maintenance and consumables) and the additional pharmaceuticals used by participants were collected during the SMARThealth Extend study. Hospital costs were estimated by the authors based on prior data collected and it was assumed that every major CVD event required one hospitalisation (Ministry of Health, Republic of Indonesia, 2014). An average cost of treating a stroke and myocardial infarction patient was used as the hospital treatment cost component and it was assumed that half CVD events experienced were in each category based on the expert opinion of the authors in the absence of more robust epidemiological data. The additional primary health care service use incurred by those receiving the intervention were estimated by the authors and costs estimated based on the literature, assuming an additional two primary care visits each year for those receiving the intervention (Stenberg et al., 2018). Future costs and health outcomes were discounted at 3% per year as per recommended guidelines (WHO, Wilkinson et al., 2016). All costs are expressed in 2018 US$ (1USD = €0.855 =14,292 Indonesian Rupiah at June 30 2018) (xe.com, 2020).

Outcome measures

Two outcome measures are used in this study to enhance comparability with the existing literature: cost per disability adjusted life-year (DALY) averted and the cost per major CVD event averted. Disability weights for people experiencing a major CVD event were adopted from the Global Burden of Disease Study (Salomon et al., 2015), using a weighted average from myocardial infarction and moderate to severe stroke weights, resulting in a DALY weight for major CVD event of 0.39. A disability weight of 1 was used to reflect the dead health state. CVD events were estimated for each treatment arm through the model. We calculated incremental cost effectiveness ratios (ICER) for both these outcomes to compare current practice to the SMARThealth intervention, defined as: [cost of the intervention – cost of current practice][effectiveness of intervention – effectiveness of current practice]. While interventions are often assessed as cost-effective if the ICER is less than a particular willingness-to-pay threshold, the appropriateness of these thresholds has been heavily debated, particularly in low- and middle-income settings (Robinson et al., 2016, Woods et al., 2016, Ochalek et al., 2015, Shillcutt et al., 2009, Marseille et al., 2014). As such, no
thresholds are specified here: instead, cost-effectiveness results are presented on a cost-effective acceptability curve to allow interpretation over a range of potential willingness to pay values.

Sensitivity analyses

To determine the robustness of our results and identify the parameters that most influence the findings, we performed extensive sensitivity analyses. One-way sensitivity analyses were performed on key model parameters (Table 1). Probabilistic sensitivity analysis was conducted to highlight the combined uncertainty of all the model parameters using second order Monte Carlo simulations. Parameter distributions for cost variables were specified by a gamma distribution (range of ±20%) and beta distribution for probabilities (range taken from published literature, or if unavailable ±0.2, constrained between 0 and 1). Uncertainty in the model is presented through a cost-effectiveness acceptability curve.

Role of the funding source

The funding sources had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review or approval of the manuscript; nor the decision to submit the manuscript for publication.

Results

There was a one-off cost of $8.35 for every person screened for level of CVD risk through the intervention (including personnel, equipment, maintenance and consumables costs). Table 2 summarises the main results of our analysis. On average, annual treatment costs for CVD management were $83 under current care and $144 for those receiving the intervention. This difference reflects from additional primary care visits and pharmaceutical use in the intervention group. Across the modelled cohort, there were 16,407 fewer CVD events and 7,113 fewer CVD-related deaths for the group receiving the intervention over 10 years. The intervention was found to yield an ICER of $4,288 per DALY averted and $3,681 per major CVD event avoided relative to usual care.

One-way sensitivity analyses (presented in Figure 3) showed the ICER results were robust to varying most parameters over plausible values. The results were most sensitive to the number of additional primary care visits by those identified as high-risk receiving the intervention, the effectiveness of the intervention and the proportion of the baseline population at high risk of CVD. If the number of additional primary care visits required by those receiving the intervention is doubled to four per year, the ICER per DALY averted increases to $8,567 (while if no additional visits are required the intervention becomes cost-saving). If the effectiveness of the intervention in averting CVD events is reduced by 5 percentage points the cost per DALY averted rises to $6,108. Similarly, if the DALY weight used to model the disability associated with surviving a major CVD event is reduced from 0.39 to 0.19, the ICER increases to $6,942 (while if a DALY weight of 0.59 instead the ICER reduces to $3,611) and if the DALY weight for a year of life with no previous CVD event in this population is increased from 0 to 0.2, the ICER increases to $6,718. The intervention is most cost-effective when a higher proportion of the population is at high CVD risk. This is explored further in Figure 4, which illustrates how varying the baseline risk of CVD in the population impacts the cost per DALY averted results. This ranged from $7,205 per DALY averted when 5% of the population were at risk of CVD to $3,850 when the entire population is at high-risk of CVD. The cost-effectiveness results were not substantially changed by changes to the other cost variables, the discount rate used or the mortality rate following major CVD events.
The cost-effectiveness acceptability curve (Figure 5) represents the probability that the new intervention will be considered cost-effective by decision-makers at a range of potential willingness to pay values. At a willingness to pay value of $5,500 there is a 99.8% probability that the intervention will be considered cost-effective. This reduces to 94%, 80% and 68% for willingness to pay values of $3,500, $2,500 and $2,000. Given Indonesia’s Gross National Income per capita in 2018 of $3,840, our results suggest that the intervention is highly likely to be considered highly cost-effective based on previously used thresholds (The World Bank Group, 2019).

Discussion

Relative to current practice, our findings suggest that the implementation of a complex technology-enabled primary care intervention is a cost-effective means to reduce the burden of major CVD events in a rural Indonesian population over the next ten years. While individuals who received the intervention had higher primary care and pharmaceutical costs, they were projected to experience fewer major CVD events and incur lower hospitalisation expenditure. We found that the intervention is likely to be considered cost-effective by decision-makers in the Indonesian context. The findings demonstrate the potential of a technology-supported intervention to empower non-physician community health workers to bridge service-access gaps in rural and resource-constrained settings and meet the longer-term care needs of individuals at high CVD risk.

Rapid sociodemographic and epidemiological change over recent decades has seen a dramatic increase in the level of CVD and other non-communicable diseases in Indonesia and other low- and middle-income nations, posing challenges to the sustainability of health systems that traditionally evolved to provide maternal care and respond to outbreaks of contagious diseases (Prabhakaran et al., 2018, Roth et al., 2015, Ezzati et al., 2018). To overcome these challenges, governments and other funders have increasingly looked to strengthen primary care systems and prevention programs across the world (Prabhakaran et al., 2018, Nugent et al., 2018). Our findings have highlighted the potential of technology-based interventions to empower community health workers to contribute these goals in a cost-effective and scalable manner. Using mobile technology, community-health workers identified individuals at high CVD and then facilitated the management of these individuals, including providing access to recommended pharmaceutical and physician treatment. By capitalising on low-cost models of primary care, the intervention was able to reach high-risk members of the population in a cost-effective manner, many of who may not have encountered the health system were it not for the outreach approach led by the kaders. By successfully targeting and reaching underserved groups in a low-resource setting, the intervention likely yields outcomes that are not only cost-effective but can also address equity considerations.

In spite of the potential of technology-enabled primary care interventions demonstrated in this study, there have been few economic evaluations to guide investment in mobile and e-health interventions in low and middle-income nations (Iribarren et al., 2017, Jiang et al., 2019). This study is an important contribution to this literature providing robust economic evidence for local decision-makers based on data collected through a large quasi-randomised study and the best available evidence in the literature. More generally, there is a shortage of economic evaluation evidence of health interventions in the Indonesian context. Our results suggest this intervention, while less cost-effective than many vaccination interventions including dengue vaccination (Zeng et al., 2018) and compares favourably to other interventions that have been assessed for cost-effectiveness including methadone maintenance therapy to avert HIV infections among intravenous drug users (Wammes et al.,
Extrapolating our results, it would cost approximately $8.7M to screen the current adult population over 40 of Malang district with the SMARThealth Extend intervention and an additional $12.3M of primary care and pharmaceutical costs annually for those at high-risk of CVD if treatment patterns and the proportion of individuals at high-risk of CVD are representative of the entire district. While a rough estimate, the embedding of the intervention into the existing health system suggests widespread roll-out could be of significant benefit to the population. Further consideration of the implications of integrating the intervention as part of usual care, including ensuring the supply of pharmaceuticals and the retention of the community health workforce, is needed to guide widespread implementation. While our study only considered care for cardiovascular diseases, similar interventions have been used in other contexts for different conditions, notably to facilitate diabetes and pregnancy related care. Expanding the intervention to incorporate care and screening for other conditions could potentially improve the benefits without significant impact on the cost or implementation of the intervention and should be further investigated.

There were limitations of our analysis that need to be considered when interpreting the findings. The parameters of the model were developed using data collected in the eight villages included in the quasi-experimental SMART health Extend study and thus may not be representative of the broader population of the district or country, particularly when projected over a ten-year period. The sensitivity analyses conducted, however, demonstrated the results to be robust against variation in the major model parameters suggesting that this may not have a major impact on results and that the study presents useful data for Indonesian policy-makers as well as those of similar jurisdictions. Our analysis adopted a health-payer perspective and did not consider contributions of patients or their carers through direct out-of-pocket costs and other economic impacts, including lost income as a result of experiencing a major CVD event or caring for someone who has. Other evidence has demonstrated the significant economic burden placed on households as a result of CVD events and if these were considered in our analysis it is likely that the cost per DALY averted results obtained in this study would be lower (Finkelstein et al., 2014).

Conclusion

The community-based technology-enabled SMART health intervention was a cost-effective mechanism to improve the management and care of individuals at high-risk of CVD in a rural Indonesian population. Leveraging mobile technology, the intervention enabled community health workers to lead the identification and management of individuals at high-risk of CVD and facilitate access to recommended, evidence-based treatments. The results demonstrate the potential of similar interventions to strengthen health systems and overcome service gaps in rural and resource constrained environments.

Abbreviations

CVD: Cardiovascular diseases
DALY: Disability-adjusted life year
ICER: Incremental cost-effectiveness ratio
WHO: World Health Organisation
References


