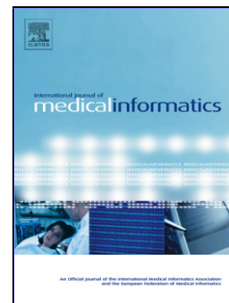# Accepted Manuscript

Article Title:

Evaluating the use of mobile phone technology to enhance cardiovascular

disease screening by community health workers

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Key words

mHealth, Community Health Workers, Cardiovascular disease risk assessment, task-shifting, mobile phones

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Abstract

Background

Primary prevention of cardiovascular disease (CVD),by identifying individuals at risk is a well-established, but costly strategy when based on measurements that depend on laboratory analyses. A non-laboratory, paper-based CVD risk assessment chart tool has previously been developed to make screening more affordable in developing countries. Task shifting to community health workers (CHWs) is being investigated to further scale CVD risk screening. This study aimed to develop a mobile phone CVD risk assessment application and to evaluate it's impact on CHW training and the duration of screening for CVD in the community by CHWs.

Methods

A feature phone application was developed using the open source online platform, CommCare©. CHWs (n=24) were trained to use both paper-based and mobile phone CVD risk assessment tools. They were randomly allocated to using one of the risk tools to screen 10-20 community members and then crossed over to screen the same number, using the alternate risk tool. The impact on CHW training time, screening time and margin of error in calculating risk scores was recorded. A focus group discussion evaluated experiences of CHWs using the two tools.

Results

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The training time was 12.3 hrs for the paper-based chart tool and 3 hours for the mobile phone application. 537 people were screened. The mean screening time was 36 minutes (SD=12.6) using the paper-base chart tool and 21 minutes (SD=8.71) using the mobile phone application , p = <0.0001. Incorrect calculations (4.3 % of average systolic BP measurements, 10.4 % of BMI and 3.8% of CVD risk score) were found when using the paper-based chart tool while all the mobile phone calculations were correct. Qualitative findings from the focus group discussion corresponded with the findings of the pilot study.

Conclusion

The reduction in CHW training time, CVD risk screening time, lack of errors in calculation of a CVD risk score and end user satisfaction when using a mobile phone application, has implications in terms of adoption and sustainability of this primary prevention strategy to identify people with high CVD risk who can be referred for appropriate diagnoses and treatment.

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Introduction

Cardiovascular disease (CVD) is the leading cause of death worldwide; with developing countries affected the worst (1-3). Screening for the risk of developing CVD is a well-recognised primary prevention strategy. This is usually done by calculating a risk score based on assessing a combination of risk factors, including, age, gender, tobacco use, blood pressure levels, blood cholesterol levels, diabetes or family history of CVD (4-6). The human resource requirements, laboratory costs as well as inconvenience to the individual of risk scores that depend on biochemical tests has led to the development of a non-laboratory based CVD risk assessment model. This simplified model substitutes the body-mass index for blood lipid level to calculate the absolute CVD risk score thus making CVD risk screening far more feasible and potentially cost effective in both high and low resource settings (7). The model uses data from a clinical history and physical examination, making a number of basic arithmetic calculations and decision support charts to calculate the CVD risk score (Fig 1.). This method has been found to perform as well as the common laboratory-based risk score in identifying people at high CVD risk in a South African setting (8).

Given the limited work force of nurses and doctors across all resource settings, the concept of task shifting is gaining increasing traction. Community health workers (CHWs) defined by the World Health Organization (WHO) as community members that have shorter training than professional workers, have

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been identified as potential candidates for task shifting in the health sector in general. CHWs have been used to provide a wide range of basic health services and it is well established that they play a crucial role in improving access to health services in under resourced settings (9). There are, however, a number of challenges in using CHWs as they tend to have a limited amount of formal education and training. Mobile health tools are increasingly being used to assist and enable lay health workers in performing basic tasks. These interventions are thought to strengthen health systems by enabling a wide range of activities including data collection, disease surveillance, monitoring and evaluation and supporting clinic based health workers (10-13).

Development of a mobile phone application that automatically calculates a CVD risk score further simplifies the task of risk assessment in the community because it allows for the risk assessment tool to be carried into the community and because it can potentially limit errors due to manual calculations. Finally, it can be used by health workers with limited formal education who may be less skilled and numerate.

The aim of this study was to develop a mobile phone CVD risk assessment application, based on a non-laboratory CVD risk assessment model and to evaluate its impacts on the training of CHWs and the screening for CVD in the community by CHWs compared to them using the paper-based chart tool.

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Figure 1: The non-laboratory CVD risk assessment chart
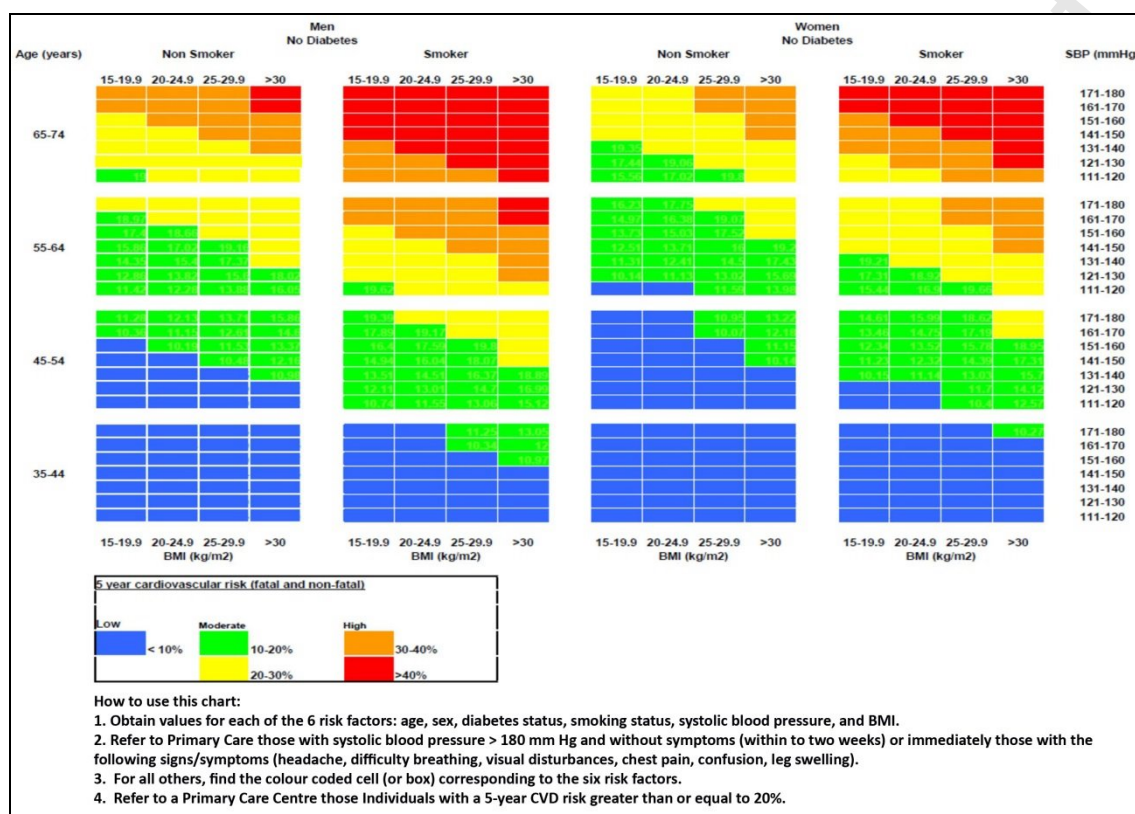
Methods

This pilot study used quantitative and qualitative research methods. A mobile

phone CVD risk assessment application was developed based on the non-

laboratory paper-based CVD risk assessment model developed and validated

by *Gaziano et al (7)*.The online CommCareHQ platform was used to develop

the mobile phone version of this tool. CommCareHQ is an open-source

software application with mobile phone and cloud infrastructure designed to

enable creation of mobile phone job aids for CHWs. Relevant data entry fields

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were organized and programmed into the application. The application was tested for question flow logic, data entry limits, error messaging and calculation accuracy.

CHWs (n=24) with no previous experience in screening for CVD were recruited through a local non-governmental organization. The CHWs underwent training in the basics of CVD (Module 1) and in learning the practical skills required for conducting CVD risk assessment (Module 2). Thereafter they were randomly allocated to training in either paper-based chart CVD risk assessment tool (group A, n=14 Module 3) or the mobile phone CVD risk application (group B, n=10, Module 4). Only CHWs who passed proficiency tests (written tests, pass mark 80%) in Modules 1, 2 and then either 3 or 4 progressed to undertake CVD risk assessments with their respective tools in the community. Each CHW screened between 10-20 community members opportunistically in the Nyanga district, Cape Town. After the first phase of fieldwork the CHWs underwent training in use of the other tool, and once again screened between 10-20 community members. The CHWs were issued with 1) basic feature phones (Nokia C3) preloaded with data and the risk assessment application or a paper-based chart tool, 2) calibrated BP monitor (OMRON M6 Comfort), Height rod (stadiometer), calibrated weighing scale, measuring tape and relevant study forms. Features phones, unlike basic phones, have the ability to access the internet but lacks the advance functionality of smart phones. The following eligibility criteria were used to screen participants for study eligibility: Aged between 35-75 years, no history of hypertension, diabetes, ischemic heart disease or cerebrovascular disease.

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The time taken to train CHWs to correctly calculate a total CVD risk score was measured during the training sessions. Training time for modules 1 and 2 were common to both paper based and phone application risk score determination and only the difference in the training time taken to learn the different tools was recorded. Training completion was measured upon the successful completion of the proficiency tests. The screening time was measured by calculating the time required for CHWs to complete CVD risk screenings. When the CHWs used the paper-based chart tool they recorded their screening start and end times on the study forms and when they used the mobile phone application the times were automatically captured. The difference in screening times between each tool was analyzed using an unpaired t-test. The impact that the order in which the tools was learnt and used to screen was also analyzed using an unpaired T-test. The margin of error in using the paper-based chart tool was determined by recalculating each risk score.

A randomly selected group of participating CHWs (n= 11), were invited to participate in a focus group discussion to gain insights into the meanings, experiences and views of the participating CHWs. Informed consent was obtained from all participating CHWs and the data from the discussion was audio recorded on voice recorders (x2). A basic interview schedule was used to facilitate discussions and the discussion was conducted in Xhosa, the home language of the CHWs. The recordings were translated into English and transcribed verbatim. Deductive qualitative analysis methods were used to draw out patterns from the concepts and insights of the CHWs in order to evaluate how their experiences in using both a paper-based tool and a mobile phone based tool compared.

The University of Cape Town Human Research Ethics Committee (HREC) approved the proposal and informed consent was obtained from all study participants.

Results

The mean age of the CHWs was 33 years (range 21 – 52 years) with 21 being female and 3 male. The level of basic education was Grade 12 (twelve years of schooling; completion of high school), n=8; Grade 11, n=14 and Grade 10, n=2. In addition, most CHWs also had some basic healthcare training in the form of Home-Based Community Care skills (n=17) or Chronic Diseases of lifestyle skills (n=4). Every participating CHW owned and was familiar with using a mobile phone with 71% (n=17) owning feature phones and 29% (n=7) owning smart phones. All CHWs utilised standard feature phones for this study.

There were 537 community members screened, of whom 60 were excluded from analysis due to incomplete records. The mean age was 44 (± 9,8 years) and 34% were men and 66% women. The participants had the following risk scores: Low Risk (74.6%); Low-Moderate Risk (16.8%); Moderate Risk (4.8%); Moderate-High Risk (2.1%); High Risk (1.7%), (fig 2.).

Figure 2. Population characteristics and levels of CVD risk
  identified

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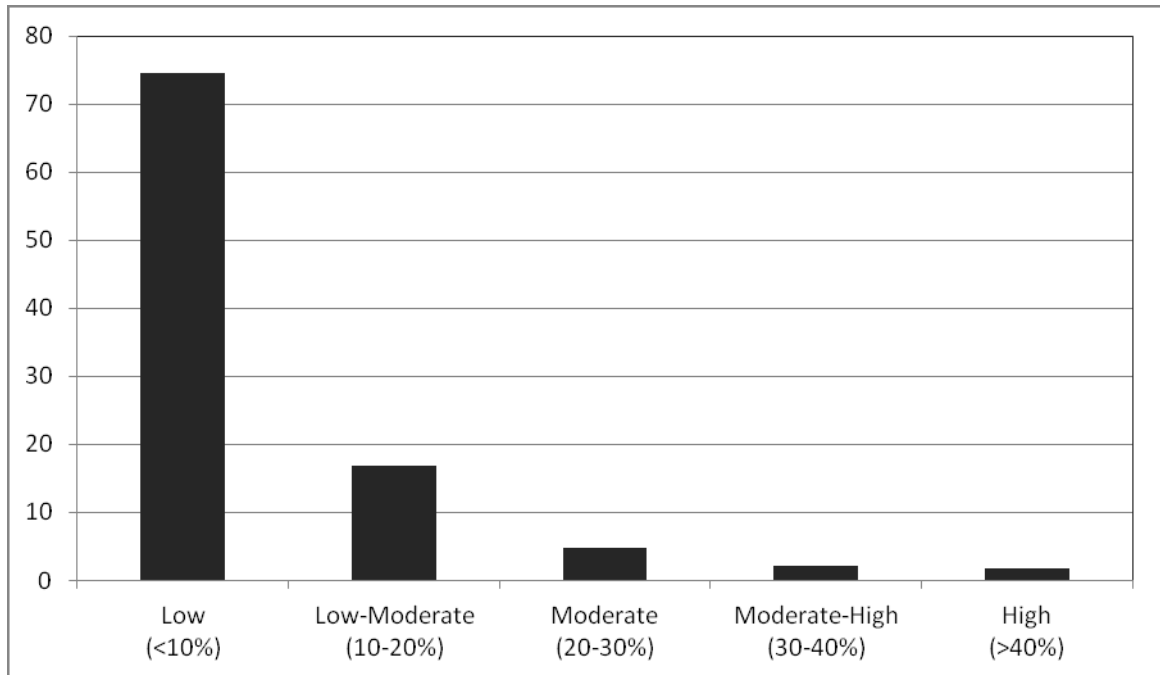
As seen in table 1, the mean training time was 4 times longer when using the paper based chart method compared to the mobile phone application method. The mean screening time was also a longer by 1/3 for paper based method (p<0.0001). There was no statistical significance in the order each tool was used and on subsequent screening time.

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Table 1. Summary of CHW training and screening results when comparing both tools.

OUTCOME MEASURE	Paper-based tool	Mobile phone tool	p-value*
Proficiency testing following training			
No. of CHW trained	22	24	
No. of CHW that passed proficiency testing	17 (77%)	23 (96%)	
Mean training time (Hours)	12,3	3	
Mean screening time (Minutes)	35.4(SD 12.6)	21.0 (SD 8.7)	<0.0001
Mean calculation time (Minutes)	7.4 (SD 6.8)		
Margin of calculation errors when using Tool A			
Averaging Systolic BP (%)	4,3		
Calculation Body mass index (%)	10,3		
Determining overall risk score (%)	3,8		

P-value calculated using unpaired T-test, # No calculations errors when using Tool B, Tool A = Paper-based Chart tool, Tool B = Mobile phone application

Qualitative results

A number of themes were identified during the focus group discussion and are summarised in table 2. CHWs felt the mobile phone application was easier, faster and more accurate to use, but noted that it was inferior to the chart as a visual aid when explaining risk.

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Table 2. Summary of the themes identified during qualitative evaluation of CHW experiences in using both tools.

Identified themes	Commentary	Extracted CHW quotes
Theme 1: Ease in using the mobile phone application	In general, it was felt that the mobile phone, in comparison to the paper-based chart tool was easier to use in order to calculate a CVD risk score.	*"…I am saying the cell phone because it is easy, you do not write down anything, you do not take that time of having to write down, you just ask what is what,"* *"The phone was easy, you loaded everything in it. For the chart you needed to check the participant's age and go to where it is on the chart and check the BMI and find it on the chart. You were to also check if s/he is smoking or not, if it is a lady that is smoking, then you go to the side with a lady smoker, so that is how it was checked."*
Theme 2: Speed in using the mobile phone application	The mobile phone was generally considered a faster tool to use by the majority of CHWs.	*"I saw the phone as the right tool because you were not taking long when using it…"* *"…The phone is faster if you know where your finger must go you see, you can measure many people in a day perhaps."*
Theme 3: Avoidance of calculation errors	The majority of CHWs felt there was less room for making mistakes, when using the mobile phone as they did not have to conduct any of the calculations manually.	*"To me it was the phone that was easy to use because with the chart some of us were making mistakes when calculating the BMI"* *"We were making mistakes where we had to make conversions, some people were forgetting to convert in those places but for the phone, you would enter the numbers only and it did everything."* *"Yes there are no errors with the phone except if you entered wrong numbers."*
Theme 4: Technical challenges in using the mobile phone application	The application only notified the user that a candidate was non-eligible (when their ave. sys. BP<110) at the end of the screening, causing some	*"…you can actually see as you calculated that s/he is non-eligible"… but when I was using the mobile phone I did not know what was happening. To me the chart was easier*

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	confusion. Another point made was that data had to be entered correctly into the mobile phone in order to get accurate results.	*than the phone."* *"When using the phone you get confused and you have to press 'back' and try to show the participant."* *"…I do not think the cell phone has many challenges but you need to enter the participant's correct and exact readings because if you become careless, things will not get right and you will get wrong information."*
Theme 5: Challenges using the paper-based chart tool	The majority of CHWs felt that the chart took longer to use as it required looking at many data points in order to determine a risk score, and was harder to use in general.	*"I struggled concerning the chart especially when calculating"*
Theme 6: Advantages of using the paper-based chart tool	However, it was also generally felt that understanding how the chart worked gave the CHWs more insight into calculating a CVD risk score and was more fulfilling to use. The mobile phone application was felt to be too simple. It was also felt that the chart was a good visual aid and was useful to use when explaining risk to clients	*"I enjoyed using the chart because you could check by yourself and see the status of the participant but when using the phone, it works out everything, it does not tell you what is wrong with the participant. I mean, when you are using the phone, it works out everything for you whereas the chart shows you. We are going to work in the community and there will be no phones, we must know where we stand."* *"…doing the calculations yourself gave you more knowledge than using a cell phone because it does everything for you. It just shows you that the person is at a risk or not, the person is eligible or non-eligible, it does all that for you, with the chart you do calculations by yourself and understand them as a result…"*

Discussion

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The major findings of this study were that the mobile phone application of a non-blood based CVD risk tool used by CHWs was associated with a major reduction in the time taken for training, reaching adequate proficiency, screening for CVD risk and an elimination of errors in calculating a CVD risk score. Further that a quarter (25.4%) of screened participants had moderate to high risk of having a CVD event in the next five years. These are individuals that were previously unaware of having any risk of CVD (i.e. had no previously diagnosed risk factors such as diabetes, hypertension or a previous history of CVD) further highlighting the need for on-going screening for CVD in these communities. The benefits of using mHealth to further simplify risk assessment shown in this study are in keeping with the gains seen in using mobile phones as job aids for unskilled health workers. (13, 14)

These findings are highly relevant as they demonstrate the challenges the CHWs faced in having to manually calculate risk scores using the chart tool. Indeed manual calculations were required at multiple steps of the paper based tool (e.g. mean of 3 blood pressures and calculation of BMI). A tool that automates the required arithmetic calculations has numerous benefits. It would potentially enable more CHWs to participate in CVD screening and not just those that are numerate. A CHW that, for example, had very good people and counselling skills, but was not fully numerate, would otherwise be excluded from being able to conduct CVD screening in the absence of a tool that automated calculations. In addition, the elimination of the risk of calculation errors makes the mobile phone application a safer and more reliable option to use in the hands of unskilled health workers. This would improve the quality of referrals

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into the health system, preventing unnecessary and unwarranted referrals. The time lost in conducting the manual calculations could be gainfully employed for further engaging and counselling with the individual being screened or for additional screening in the community. As a screening tool the mobile phone application was accepted and preferred by the CHWs which have positive implications in terms of user adoption and therefore the potential sustainability of using mHealth tools for the purposes of CVD primary prevention.

Both the mobile phone application and the paper-based chart only produce an overall risk score and don't inform the screened individual as to the various risk factors that require modification. It is well established that risk scores do not necessarily lead to better outcomes unless those at risk have their risk factors modified and controlled over time (15, 16). This model of decentralized CVD risk assessment will only prove successful if high risk individuals are appropriately referred and followed up on. Further research is needed to evaluate how effectively these individuals are connected to the health system and managed over time once they are identified as high risk of CVD. A major limitation of the mobile phone application, identified by the CHWs, was that it was not as easy to explain the concept of 'risk' as when using the paper-based chart tool, where the chart proved to be a useful and colourful visual aid (fig 1). How the concept of 'risk' is understood by individuals in the community remains unknown and also requires further evaluation.

The ideal and most cost-effective CVD risk screening test is one that can accurately identify those people at highest CVD risk that will benefit most by referral for definitive diagnoses and appropriate treatment. The findings of this

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study contribute to the work being done to decentralize and simplify CVD risk assessment and to make it possible to be performed unskilled health workers in community settings.

Conclusion

This study has found that when CHWs were trained to use a non-blood based CVD risk tool, compared to the paper-based chart tool, the mobile phone application was associated with a major reduction in the time taken for training and reaching adequate proficiency, in the time taken to screen individuals and there was elimination of errors in calculating a CVD risk score. The increased efficiency with reduced screening times and faster and easier training could have cost saving implications and the reduction in calculation errors implies an overall improvement in the safety, reliability and accuracy of CVD risk determination compared to using the paper-based chart tool.This work illustrates how a mHealth tool can be used in conjuncture with other strategies, such as the non-laboratory based CVD risk model and task shifting to CHWs, to enhance the screening for CVD. This is relevant in a low-resource setting like South Africa, where the development of affordable, scalable and sustainable cardiovascular disease primary prevention strategies is a priority. It is also a strategy that, due to the widespread availability and familiarity with mobile phone technology, can easily be replicated in other low-income settings around the world.

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Conflict of interest declaration:

None declared by any of the authors.

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Summary table

What was already known on the topic:

• A non-laboratory, paper-based CVD risk assessment chart tool has been developed to make screening more affordable in developing countries.
• This tool requires numerous arithmetic calculations and use of a cross referencing decision support chart to determine a risk score.
• Task shifting to community health workers (CHWs) is being investigated to further scale CVD risk screening. This method can be challenging as CHWs have varying levels of basic education.
• Mobile phone technology is increasingly being used as a job aids for CHWs.

What this study added to our knowledge:

• The mobile phone application was found to be associated with a 1) decrease in CHW training time, 2) decrease in CVD risk screening time and 3) elimination in errors in calculating a CVD risk score.
• Reducing calculation errors leads to improved overall safety, reliability and accuracy of CVD risk determination.
• The increased efficiency with reduced screening times and the faster and easier training could have cost-benefit implications.
• The task-shifting of CVD risk assessment to lesser skilled health workers can be enhanced using mobile phone technology.

Highlights

➤ Enhanced screening with the mHealth tool compared to the paper-based chart tool

➤ Reduction in screening times by 40% (21 min vs 35min)

➤ Reduction in community health worker training times by 76% (3hrs vs 12.3 hrs)

➤ Elimination in the margin of error in calculating a CVD Risk score.

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Author Contributions

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Dr Sam Surka (1) the conception and design of the study, (2) acquisition of data, analysis and interpretation of data, (3) drafting the article, revising it critically for important intellectual content

Dr Sisira Edirippulige,(1) interpretation of data, (2) revising it critically for important intellectual content, (3) final approval of the version to be submitted.

Prof Krisela Steyn (1) the conception and design of the study, (2) interpretation of data, (3) revising it critically for important intellectual content, (4) final approval of the version to be submitted

Dr Thomas Gaziano, (1) the conception and design of the study, (2) interpretation of data, (3) revising it critically for important intellectual content

Prof Thandi Puoane, (1) the conception and design of the study, (2) acquisition of data, (3) interpretation of data, (4) revising it critically for important intellectual content

Prof Naomi Levitt, (1) the conception and design of the study, (2) interpretation of data, (3) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted

SS acquired, analysed the data and drafted the article.

SS, KS, TG, TP and NL conceptualized and designed the study.

SS, SE, KS, TG, TP and NL interpreted and critically revised the data