ABSTRACT

Introduction: The Framingham risk model estimates a person's 10-year cardiovascular disease (CVD) risk. This study used this model to calculate the changes in sex- and age-specific CVD risks in the Hong Kong Population Health Survey (PHS) 2014/2015 compared with two previous surveys conducted during 2003 and 2005, namely, PHS 2003/2004 and Heart Health Survey (HHS) 2004/2005.

Methods: This study included individuals aged 30 to 74 years from PHS 2014/2015 (n=1662; n=4 445 868 after population weighting) and PHS 2003/2004 and HHS 2004/2005 (n=818; n=3 495 074 after population weighting) with complete data for calculating the risk of CVD predicted by the Framingham model. Sex-specific CVD risks were calculated based on age, total cholesterol and high-density lipoprotein cholesterol levels, mean systolic blood pressure, smoking habit, diabetic status, and hypertension treatment. Mean sex- and age-specific CVD risks were calculated; differences in CVD risk between the two surveys were compared by independent t tests.

Results: The difference in 10-year CVD risk from 2003-2005 to 2014-2015 was not statistically significant (10.2% vs 10.6%; P=0.29). After age standardisation according to World Health Organization world standard population data, a small decrease in CVD risk was observed, from 9.4% in 2003-2005 to 8.8% in 2014-2015. Analysis according to age-group showed that more participants aged 65 to 74 years were considered high risk in 2003 to 2005 (2003-2005: 66.8% vs 2014-2015: 53.1%; P=0.028). This difference may be due to the decrease in smokers among men (2003-2005: 30.5% vs 2014-2015: 24.0%; P<0.001).

Conclusion: From 2003-2005 to 2014-2015, there was a small decrease in age-standardised 10-year CVD risk. A holistic public health approach simultaneously targeting multiple risk factors is needed to achieve greater decreases in CVD risk.

New knowledge added by this study
- The stagnation in 10-year cardiovascular disease (CVD) risk between 2003 and 2015 suggests that despite improvements in treatment, more effective prevention strategies (eg, improvements in diet and physical activity levels) are needed.
- The effect of the decreasing number of current smokers was not strongly reflected in the change in 10-year CVD risk. This may be due to an increased prevalence of diabetes and an increased proportion of participants receiving antihypertensive medications.

Implications for clinical practice or policy
- The findings suggest that the use of lipid-lowering drugs and antihypertensive medications does not effectively translate into overall cardiovascular risk reduction in the Hong Kong population, unless these treatments are simultaneously paired with prevention strategies targeting CVD risk factors.
**Introduction**

Cardiovascular disease (CVD) constitutes a spectrum of diseases that affect the heart and blood vessels. Worldwide, CVD is the leading cause of death as well as a major cause of premature death and chronic disability in numerous regions.¹ In 2017, CVD was responsible for an estimated 17.8 million deaths, representing 31% of all global deaths.² Hypertension, smoking status, hyperlipidaemia, and diabetes mellitus are prominent risk factors for CVD.³ The global prevalence of CVD risk factors is increasing. Currently, an estimated 15% of the world’s population (1.13 billion people) has hypertension, and the prevalence is expected to increase to 29% by 2025.⁴ ⁵ Additionally, the global prevalence of diabetes increased from 211 million in 1990 to 476 million in 2017, representing a 129.7% increase in nearly three decades.⁶ The prevalences of CVD and its risk factors are expected to continue to increase in the near future due to industrialisation and population ageing. Fortunately, the World Health Organization (WHO) has estimated that premature CVD is preventable in >75% of cases, and risk factor amelioration can help reduce the burden caused by CVD.⁷

The risk of CVD over the next 10 years for an individual can be estimated using prediction models. Cardiovascular disease risk prediction is important at the individual and population levels. At the individual level, CVD risk prediction allows primary care medical professionals to identify high-risk patients. Risk factors for CVD, such as hypertension, can be treated accordingly to reduce the patient’s future risk of CVD. At the population level, CVD risk trends allow health policy planners to make evidence-based decisions and review current public health strategies used in CVD prevention.⁸

Changes in CVD risk can serve as a reference to indicate changes in public health status within a population. Two studies have evaluated changes in the 10-year CVD risk in the United States (US) population. In a study by Ajani and Ford,⁹ risk models adopted by the National Cholesterol Education Program Adult Treatment Panel III were utilised to estimate coronary heart disease risk, rather than the more precise Framingham formulae for estimation of overall CVD risk. Notably, their analysis lacked age stratification. On the other hand, Lopez-Jimenez et al¹⁰ evaluated the changes in CVD risk between 1976 and 2004. To our knowledge, no previous study has evaluated the change in 10-year CVD risk in an Asian population, and insights are needed regarding the cardiovascular health status of the population in a more recent time period.

In this study, we aimed to calculate and compare the changes in sex- and age-specific CVD risks predicted by the Framingham model in a Hong Kong general population by using the Hong Kong Population Health Survey (PHS) 2014/2015 in combination with two previous surveys conducted in 2003 to 2005, namely, PHS 2003/2004 and Heart Health Survey (HHS) 2004/2005.

**Methods**

**Study design and sampling**

The data in this study were sourced from PHS 2003/2004¹¹ and PHS 2014/2015.¹² Population Health Surveys are territory-wide cross-sectional surveys conducted by the Department of Health of the Hong Kong SAR Government. These surveys target the land-based non-institutional population of individuals aged ≥15 years in Hong Kong, excluding foreign domestic helpers and visitors. Systematic replicate sampling was adopted to select living quarters that were representative of the Hong Kong general population. All domestic households in the selected living quarters and household members in the target population were individually surveyed. Written consent was obtained from individuals.
who agreed to participate in a PHS. Participants were invited to complete a face-to-face interview, where they provided information about their socio-demographic characteristics, disease status, and daily lifestyle habits. After the interview, consenting participants aged 15 to 84 years were randomly selected to undergo a health examination that included physical measurements and biochemical testing. Health examinations for participants of PHS 2003/2004 were conducted as part of the HHS 2004/2005.

The STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist was followed for preparing this manuscript.

Predicted risk of cardiovascular disease over the next 10 years

The main outcome of this study was the predicted risk of CVD over the next 10 years among people aged 30 to 74 years. Thus far, no specific prediction models have been developed for the Hong Kong population. In this study, we adopted the prediction model for primary care developed by the Framingham Heart Study Cohort in the general adult population aged 30 to 74 years. The Framingham CVD risk model was validated and can be applied to the Chinese population, but requires recalibration in men. A CVD event was defined as a composite of coronary heart disease, cerebrovascular events, peripheral artery disease, and heart failure in the Framingham model. The predicted CVD risk over the next 10 years was calculated for each participant using the following information: age, total cholesterol level, high-density lipoprotein cholesterol level, systolic blood pressure, use of antihypertensive medication, current smoking status, and diabetes status.

Statistical analysis

A complete-case analysis approach was utilised in this study. Descriptive statistics were used to present the characteristics of included individuals. Sex- and age-specific predicted CVD risks in 2003-2005 and 2014-2015 were calculated to summarise the change in risk according to sex and age-group. Significant differences in the above factors between the two PHSs were tested by independent t test or Chi squared test, as appropriate.

To summarise results at the population level, population weighting established by the Department of Health was applied according to age-group and sex for participants in each PHS. To compare results at the population level, age-standardised predicted CVD risk was calculated using WHO 2000-2025 world standard population data and the US population census data in 2000.

All statistical analyses were performed with SPSS software (Windows version 26.0; IBM Corp, Armonk [NY], US). All significance tests were two-tailed, and P values <0.05 were considered statistically significant.

Results

In total, 1662 and 818 participants were included in the PHS 2014/2015 cohort and the PHS 2003/2004 and HHS 2004/2005 cohort, respectively. These individuals represented populations of 4 445 868 and 3 495 074, respectively. Table 1 shows the baseline characteristics of the PHS and HHS cohorts according to Framingham predictors. The mean age

<table>
<thead>
<tr>
<th>TABLE 1. Summary statistics for risk factors among the participants in the health surveys</th>
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</thead>
<tbody>
<tr>
<td>Sample level</td>
</tr>
<tr>
<td>Female (n=864)</td>
</tr>
<tr>
<td>Age, y</td>
</tr>
<tr>
<td>Total-C, mg/dL</td>
</tr>
<tr>
<td>HDL-C, mg/dL</td>
</tr>
<tr>
<td>Systolic BP, mm Hg</td>
</tr>
<tr>
<td>BP treatment</td>
</tr>
<tr>
<td>Smoking</td>
</tr>
<tr>
<td>Diabetes</td>
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Abbreviations: BP = blood pressure; HDL-C = high-density lipoprotein cholesterol; HHS = Heart Health Survey; PHS = Population Health Survey; total-C = total cholesterol
* Data are shown as No. (%) or mean ± standard deviation
was similar in both cohorts (2003-2005: 48.6 years vs 2014-2015: 50.8 years) and the proportions of male and female participants were similar (female participants in 2003-2005: 54.1% vs 2014-2015: 53.0%).

Predicted CVD risk increases with age and is higher in men (Table 2). In PHS 2003/2004 and HHS 2004/2005, the mean CVD risk increased with age in both sexes, from 1.6% among women aged 30-44 years to 17.8% among women aged 65-74 years, and from 5.1% among men aged 30-44 years to 33.4% among men aged 65-74 years. Between the two surveys, there was no significant difference in overall 10-year CVD risk (2003-2005: 10.2% vs 2014-2015: 10.6%; P=0.29). After age standardisation according to WHO world standard population data, the age-standardised predicted CVD risks in the 2003-2005 cohort and the 2014-2015 cohort were 9.4% and 8.8%, respectively (Table 3). The small decrease in predicted CVD risk may be due to the decrease in smokers among men (30.5% vs 24.0%; P<0.001) [Table 1].

The risk of cardiovascular events over the next 10 years was classified as low (CVD risk <10%), medium (CVD risk ≥10% and <20%), and high (CVD risk ≥20%); the distributions of risk groups are presented in Table 4. Among participants aged 30 to 74 years, the risk group distributions were similar in both cohorts. When analysed according to sex, 29.1% of men and 51.1% of women were classified as high-risk in PHS 2014/2015, whereas 28.2% of men and 6.4% of women were classified as high-risk in PHS 2003/2004 and HHS 2004/2005. When analysed according to age-group, more participants aged 65 to 74 years were classified as high-risk in PHS 2003/2004 and HHS 2004/2005 (66.8% vs 2014-2015: 53.1%; P=0.028).

**Discussion**

Using representative samples from the Hong Kong PHS and HHS, we found that the 10-year CVD risk increases with age and is consistently higher in men (men: 15.5% vs women: 6.2%; P<0.001, in PHS 2014/2015) [Table 2]. This trend is consistent with previous reports; for example, an analysis of NHANES (National Health and Nutrition Examination Survey) III data showed that men have a significantly higher CVD risk (11.8% in men vs 5.1% in women) and that CVD risk is higher in older age-groups (16.2% for participants aged 60-74 years vs 11.2% for participants aged 50-59 years). Thus, risk management for older adults may represent a challenge to the current health infrastructure. The burden of CVD is directly associated with increased morbidity and mortality in patients, and it translates to substantial healthcare costs. In Hong Kong, the number of people aged ≥65 years is predicted to reach 2.58 million (35.9% of the population) by 2064. Thus, there is a critical need to achieve a more comprehensive understanding of the aetiologies associated with CVD in older adults.

The results have extensive public health implications. Although age-standardised rates of death from CVD in Hong Kong greatly decreased from 93.4 per 100 000 standard population in 2001 to 56.0 per 100 000 standard population in 2017, there was no significant difference in overall 10-year CVD risk between 2003-2005 and 2014-2015 (10.2% vs 10.6%; P=0.29) [Table 2]. After age standardisation according to WHO world standard population data, a small decrease in CVD risk was observed, from

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**Table 2.** Mean weighted 10-year cardiovascular disease risk predicted by the Framingham model among participants aged 30 to 74 years in the health surveys according to age-group and sex

<table>
<thead>
<tr>
<th>Age-group, y</th>
<th>PHS 2014/2015 (n=4,445,868)</th>
<th>PHS 2003/2004 and HHS 2004/2005 (n=3,495,074)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>Male</td>
<td>Total</td>
</tr>
<tr>
<td>30-44</td>
<td>1.5%</td>
<td>4.1%</td>
</tr>
<tr>
<td>45-54</td>
<td>4.7%</td>
<td>11.7%</td>
</tr>
<tr>
<td>55-64</td>
<td>8.9%</td>
<td>23.0%</td>
</tr>
<tr>
<td>65-74</td>
<td>15.7%</td>
<td>33.2%</td>
</tr>
<tr>
<td>30-74</td>
<td>6.2%</td>
<td>15.5%</td>
</tr>
</tbody>
</table>

**Table 3.** Age-standardised estimates of cardiovascular disease risk for the participants of the health surveys

<table>
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<tbody>
<tr>
<td>10.6%</td>
<td>10.2%</td>
<td>8.8%</td>
</tr>
<tr>
<td>10.0%</td>
<td>10.0%</td>
<td>10.0%</td>
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</tbody>
</table>

Abbreviations: CVD = cardiovascular disease; HHS = Heart Health Survey; PHS = Population Health Survey; WHO = World Health Organization
9.4% in 2003-2005 to 8.8% in 2014-2015 [Table 3]. A study of NHANES data revealed a similar trend, consisting of a small decrease in CVD risk from 1988 to 2004 (7.9% to 7.4%; P<0.001). The stagnation in 10-year CVD risk between 2003-2005 and 2014-2015 suggests that despite improvements in treatment, more effective prevention strategies (eg, improvements in diet and physical activity levels) are needed. Primary care intervention to manage modifiable risk factors, such as hypertension, dyslipidaemia, and diabetes, can complement population-based policies. Efforts to ensure access to appropriate healthcare and affordable medications will help control abnormal risk factor levels. Furthermore, despite the importance of targeting individual risk factors to reduce prevalence, the long-term objective should be reduced overall risk of CVD. This objective requires a holistic approach simultaneously targeting multiple risk factors.

Our results highlight the need for overall risk assessment, in addition to targeted efforts focused on specific CVD risk factors. During the past decade, numerous public health initiatives (eg, smoking cessation campaigns) have been implemented to reduce the prevalence of established risk factors for CVD. It is reasonable to expect that CVD risk would decrease over time in conjunction with the decreased prevalences of various risk factors, such as the declining number of current smokers. Surprisingly, these changes were not strongly reflected in the change in 10-year CVD risk. One explanation is that decreases in the prevalence of some risk factors are offset by increases in others. For example, population ageing in Hong Kong may shift more adults into the high-risk group. However, because the Framingham model was limited to individuals aged 30 to 74 years, the change in mean age between the two surveys is inconsequential. Other possible changes in risk factors include increases in the prevalence of diabetes and hypertension, as reflected by the increased proportion of participants receiving antihypertensive medications (Table 1). Although CVD mortality has considerably decreased, it is concerning that CVD risk has not substantially diminished over the past decade. This lack of improvement in CVD risk may lead to an increasing community burden of CVD in the near future, especially in the context of population ageing.

The overall 10-year CVD risk for participants aged 30 to 74 years in 2003-2005 after age adjustment to US census population data in 2000 was 10.7%. During a similar time period (1999-2004), the US population had a 10-year CVD risk of 7.4%. When Hong Kong men were stratified according to risk group in 2014-2015, 48.8% were classified as low-risk, 22.1% were classified as medium-risk, and 29.1% were classified as high-risk (Table 4). For comparison, among men in the United Kingdom population during 2012, 46.5% were classified as low-risk, 39.9% were classified as medium-risk, and 13.6% were classified as high-risk using the National Institute for Health and Care Excellence Framingham risk model. In terms of risk distribution, a greater proportion of Hong Kong men were classified as high-risk compared with men in the United Kingdom in the early 2010s. In terms of age-standardised risk, the Hong Kong population had a higher 10-year CVD risk than the US population in 2003. Analysis according to age showed that the proportion of low-risk participants increased from 2003-2005 to 2014-2015, particularly in the age-groups of 55-64 and 65-74 years (2003-2005: 28.5% vs 2014-2015: 44.7% for participants aged 55-64 years, and 6.1% vs 15.4% for participants aged 65-74 years) [Table 4]. This increased proportion may be the result of primary care clinicians recognising age as a prominent risk factor for CVD, leading to more aggressive treatment of modifiable risk factors. Furthermore, there were fewer male smokers in...
model may overestimate the 10-year CVD risk for causing inaccuracies in the results. Additionally, the proportion of the overall sample lacking a history of CVD might have been included in the study, the Framingham risk model was developed for Caucasians, the predicted 10-year CVD risk in the Framingham cohort primarily consisted of non-Hispanic whites, and may lead to reporting bias. Considering the effort required to complete the long questionnaires, the collected data may be susceptible to non-response bias and recall bias. Furthermore, because the Framingham cohort primarily consisted of Caucasians, the predicted 10-year CVD risk in the Hong Kong population calculated using the Framingham model should be interpreted cautiously. The Framingham risk model was developed for people without a history of CVD; thus, a small proportion of the overall sample lacking a history of CVD might have been included in the study, causing inaccuracies in the results. Additionally, the model may overestimate the 10-year CVD risk for men in Hong Kong, and a recalibrated model with greater predictive power may be required. Although several limitations and assumptions may hinder the prediction of CVD risk, these potential sources of bias were present in both surveys. Therefore, the effects of such biases may be less important when comparing the change in predicted 10-year CVD risk between the two time points.

**Conclusion**

During the period from 2003-2005 to 2014-2015, the change in predicted 10-year CVD risk was not statistically significant. However, the proportion of low-risk participants within older age-groups was higher in PHS 2014/2015 than in PHS 2003/2004 and HHS 2004/2005. More aggressive CVD prevention strategies and primary care interventions are needed to address CVD risk factors.

**Strengths and limitations**

This study was based on two Hong Kong population health surveys, and thus the sample is highly representative of the general population. Baseline data were collected through laboratory tests and face-to-face interviews, suggesting that these data are highly reliable. The long interval between the two health surveys (2003-2005 to 2014-2015) also provides insights regarding the effectiveness of current CVD prevention strategies. Limitations of the current study involve its use of the Framingham risk prediction model and the PHS and HHS. Similar to other surveys, the PHS and HHS are susceptible to participation bias because the sample data might not provide an accurate representation of the overall population. Many PHS variables are self-reported and may lead to reporting bias. Considering the effort required to complete the long questionnaires, the collected data may be susceptible to non-response bias and recall bias. Furthermore, because the Framingham cohort primarily consisted of Caucasians, the predicted 10-year CVD risk in the Hong Kong population calculated using the Framingham model should be interpreted cautiously. The Framingham risk model was developed for people without a history of CVD; thus, a small proportion of the overall sample lacking a history of CVD might have been included in the study, causing inaccuracies in the results. Additionally, the model may overestimate the 10-year CVD risk for men in Hong Kong, and a recalibrated model with greater predictive power may be required. Although several limitations and assumptions may hinder the prediction of CVD risk, these potential sources of bias were present in both surveys. Therefore, the effects of such biases may be less important when comparing the change in predicted 10-year CVD risk between the two time points.

**Conclusion**

During the period from 2003-2005 to 2014-2015, the change in predicted 10-year CVD risk was not statistically significant. However, the proportion of low-risk participants within older age-groups was higher in PHS 2014/2015 than in PHS 2003/2004 and HHS 2004/2005. More aggressive CVD prevention strategies and primary care interventions are needed to address CVD risk factors.
Ethics approval
The requirement for ethics approval for this research was waived by the Institutional Review Board of The University of Hong Kong/Hospital Authority Hong Kong West Cluster, Hong Kong as this study involved secondary analysis of de-identified governmental data.

References