Background: This study examined the prevalence of airline pilots who have an excessive cardiovascular disease (CVD) risk score according to the New Zealand Guideline Group (NZGG) Framingham-based Risk Chart and describes their cardiovascular risk assessment and investigations. Methods: A cross-sectional study was performed among 856 pilots employed in an Oceania based airline. Pilots with elevated CVD risk that had been previously evaluated at various times over the previous 19 yr were reviewed retrospectively from the airline's medical records, and the subsequent cardiovascular investigations were then described. Results: There were 30 (3.5%) pilots who were found to have 5-yr CVD risk score of 10–15% or higher. Of the 29 pilots who had complete cardiac investigations data, 26 pilots underwent exercise electrocardiography (ECG), 2 pilots progressed directly to coronary angiograms and 1 pilot with abnormal echocardiogram was not examined further. Of the 26 pilots, 7 had positive or borderline exercise tests, all of whom subsequently had angiograms. One patient with a negative exercise test also had a coronary angiogram. Of the 9 patients who had coronary angiograms as a consequence of screening, 5 had significant disease that required treatment and 4 had either trivial disease or normal coronary arteries. Conclusion: The current approach to investigate excessive cardiovascular risk in pilots relies heavily on exercise electrocardiograms as a diagnostic test, and may not be optimal either to detect disease or to protect pilots from unnecessary invasive procedures. A more comprehensive and accurate cardiac investigation algorithm to assess excessive CVD risk in pilots is required.

Keywords: exercise test, Framingham risk score, occupational group, stress test.

PERIODIC MEDICAL examinations in asymptomatic airline pilots, including screening for cardiovascular disease (CVD), are conducted to detect those who are at increased risk of incapacitation (16). One of the methods utilized in the cardiovascular screening program is the application of a CVD risk score. This encompasses a risk prediction model to generate an absolute risk of CVD over a particular time frame (13). The most widely used risk prediction equations have been derived from the Framingham Heart Study (1,12). The basic Framingham Risk Score (FRS) incorporates multiple risk factors including age, gender, total cholesterol, HDL cholesterol, blood pressure, left ventricular hypertrophy on an electrocardiogram (ECG), diabetes, and smoking status (1). Different methods of assessment have been applied by different countries to allow application for different cardiovascular conditions (23).

The Civil Aviation Authority (CAA) of New Zealand evaluates the CVD risk of all Medical Certificate applicants who are over 35 yr of age (8), using the adjusted Framingham based method published by the New Zealand Guideline Group (NZGG) in 2003 and updated in 2009 (7,19,20). Some additional adjustments made by the NZGG include factors known to indicate risk elevation, which were not present in the basic equation (12). These additional factors add a 5% absolute increase in risk in people who have at least one of these risk factors; family history of premature ischemic heart disease (IHD), ischemic stroke in a first-degree male relative before the age of 55 yr or a first-degree female relative before the age of 65 yr, ethnicity (Maori, Pacific, or Indian subcontinent), diabetes and microalbuminuria, type 2 diabetes for more than 10 yr, or an HbA1c greater than 8%. In addition, the adjustments also consider isolated single risk factors, such as total cholesterol greater than 8 mmol L⁻¹, total cholesterol – HDL ratio more than 8 and blood pressure consistently greater than 170/100 mmHg. Individuals with any of these risk factors automatically have a CVD risk score greater than 15% per 5 yr. The NZGG method yields 5-yr risk estimations of < 2.5%, 2.5–5%, 5–10%, 10–15%, 15–20%, and > 20% (19,20).

For the purpose of the CAA medical standards, a 5-yr CVD risk of 10% (approximate 10-yr CVD risk of 20%) or higher is considered as being “excessive” (7). Pilots exceeding this threshold are required to demonstrate normal myocardial perfusion by undergoing further investigation, commonly through an exercise stress test. In some cases, a more demanding functional test, such as a stress echocardiography or stress nucleotide scan, might be recommended. If the functional test shows either an ambiguous or a positive result, the pilot will be considered for further investigation and coronary angiography may be required (7,8). The concern about the requirement to demonstrate normal coronary perfusion is that all of the functional tests have limited diagnostic accuracy in asymptomatic patients (5), however, coronary
angiography is an invasive procedure with some associated harms raising the possibility that pilots are subjected to unnecessary risks (10,15).

The investigations of airline pilots with an excessive CVD risk score is not well described in the literature. There is a lack of information on medical investigations undertaken as a result of an excessive CVD risk score and the extent of cardiovascular disease that this approach uncovers. This study examined the prevalence of airline pilots who have an excessive CVD risk score according to NZGG’s Framingham-based risk chart, and describes their CVD risk assessment and investigations.

METHODS

The study population consisted of 856 pilots employed in an Oceania-based airline in 2010. A cross-sectional study was performed in May 2011 to measure the prevalence of airline pilots with an excessive CVD risk score. An excessive 5-yr cardiovascular risk score was defined as having a CVD risk score of 10–15% or higher for the first time before the occurrence of a cardiovascular event. Pilots’ medical records at the airline’s medical unit were reviewed retrospectively to identify pilots that had been previously evaluated for the increased risk, and assess the cardiovascular investigations undertaken once an excessive CVD risk score had been defined.

We compared pilots with excessive risk scores with the airline pilots’ data whose 5-yr CVD risk score was lower than 10%. The comparison data were derived from pilots who conducted their medical certificate renewal between November 1, 2009 and October 31, 2010 at the airline’s medical unit. Because all members of the excessive risk group were male, only male pilot’s data were included in the comparative group, resulting in 595 pilots in the comparison group.

The continuous data were summarized as mean and standard deviation (SD) or median and interquartile range (IQR) as appropriate. The categorical data were presented as frequency and proportion (%) within column. Differences between groups were analyzed descriptively. PASW 18 software (IBM, NY) was used to perform the descriptive analyses.

The cardiovascular investigation data of the pilots with excessive risk score are presented descriptively. This study was part of an observational study to explore pilot’s morbidity and was approved by the Northern X Regional Ethics Committee of New Zealand.

RESULTS

There were 30 pilots who were found to have a 5-yr cardiovascular risk score of 10–15% or higher, as calculated using the NZGG risk method. Of these, 25 pilots had 5-yr CVD risk score of 10–15%, and 5 pilots had 5-yr CVD risk score of 15–20%. The cardiovascular investigations of these pilots were done at various times between 1992 and 2011.

These pilot’s age ranged from 44 to 64 yr old, with a mean (SD) of 55.8 (5.4) years, and a median (IQR) of 57 (8) years. All were men, with a median (IQR) flight time of 18,050 (5625) hours.

The cardiovascular risk factors of pilots with excessive risk scores and pilots with low risk scores is presented in Table I. Risk factors assessed during cardiovascular risk assessment, included age, smoking history, diabetes status, history of hypertension, systolic blood pressure, diastolic blood pressure, history of hyperlipidemia, HDL cholesterol, triglyceride, and total cholesterol-HDL ratio.

Among those with 5-yr risk of 10% or higher, nine (30%) pilots received the NZGG additional factor 5% increase; eight pilots had a family history of premature ischemic heart disease; and one pilot had type 2 diabetes with an HbA1c greater than 8%. Additionally, two pilots automatically had a 5-yr risk score greater than 15% due to having isolated single risk factors; one pilot had a total cholesterol greater than 8 mmol · L⁻¹; and one pilot had a total cholesterol-HDL ratio greater than 8.

Of the 30 pilots with an excessive risk score, 29 pilots’ cardiovascular investigation data were available. One pilot’s cardiovascular examination report was unavailable as he had his medical assessment elsewhere. An algorithm illustrating the cardiac investigations of these pilots is presented in Fig. 1.

There were nine abnormal resting ECG results found among the high risk pilot group. These included T wave abnormalities in one pilot, sinus bradycardia in two pilots, borderline first degree heart block in two pilots, left ventricular hypertrophy by voltage criteria in one pilot, and partial right bundle branch block in three pilots.

Three pilots did not have exercise stress electrocardiograms. In two cases, this was due to symptoms consistent with ischemic heart disease, including recurrent and intermittent chest discomfort and both these patients were referred directly for a coronary angiography.

<table>
<thead>
<tr>
<th>Cardiovascular risk factor</th>
<th>5-yr Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≥10%</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>57 ± 8</td>
</tr>
<tr>
<td>Body Mass Index (kg · m⁻²)</td>
<td>27 ± 4</td>
</tr>
<tr>
<td>Current cigarette smoker, n (%)</td>
<td>8 (26.7)</td>
</tr>
<tr>
<td>Alcohol consumption (units/week)</td>
<td>7 ± 8</td>
</tr>
<tr>
<td>Diabetes, n (%)</td>
<td>3 (10.0)</td>
</tr>
<tr>
<td>History of hypertension, n (%)</td>
<td>11 (36.7)</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>137 ± 20</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>82 ± 10</td>
</tr>
<tr>
<td>History of hyperlipidemia, n (%)</td>
<td>12 (40.0)</td>
</tr>
<tr>
<td>Total Cholesterol (mmol · L⁻¹)</td>
<td>5.4 ± 1.7</td>
</tr>
<tr>
<td>HDL Cholesterol (mmol · L⁻¹)</td>
<td>1.1 ± 0.3</td>
</tr>
<tr>
<td>Triglycerides (mmol · L⁻¹)</td>
<td>1.6 ± 1.2</td>
</tr>
<tr>
<td>Total Cholesterol-HDL ratio</td>
<td>5.0 ± 1.6</td>
</tr>
<tr>
<td>A ‘one off’ 5% increase, n (%)</td>
<td>9 (30.0)</td>
</tr>
<tr>
<td>Isolated elevated single risk factors</td>
<td>2 (6.7)</td>
</tr>
</tbody>
</table>

* Data presented as median ± IQR, unless otherwise stated.

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**Table I. Cardiovascular Risk Factors of Pilots with Excessive Risk Scores and Pilots with Low Risk Scores According to New Zealand’s Framingham-Based Risk Chart.**
One pilot had significant lesions, and the other had mild disease. One pilot was referred for an echocardiography, following the finding of a systolic murmur, which indicated moderate aortic valve sclerosis with moderate aortic regurgitation.

There were 26 pilots who underwent exercise stress ECGs. These tests were negative in 19 patients, and 18 of these patients did not undergo any further testing. However, one patient who had an abnormal resting ECG but a normal exercise test was referred for stress echocardiography. The stress echocardiogram was normal, but the patient was then referred for a coronary angiogram which showed a severe distal left anterior descending (LAD) atheroma (stenosis was within a 1 mm artery) with no significant proximal stenosis. This was managed medically.

In three cases, the exercise stress ECG was judged to be borderline; two pilots had mild ST segment depression and one pilot developed borderline (0.5mm) ST depression at the end of the test (12 min). Two of these patients were referred for stress echocardiography, which were normal. Both then underwent coronary angiography; one had severe disease, the other had normal coronary arteries. One of the three patients with borderline ECG results was referred for a stress nucleotide scan, which showed an abnormality (minor reversible apical defect) and on coronary angiography this patient was found to have significant disease.

In four cases, the exercise stress ECG was judged to be positive. In three patients, the ECG showed 1mm to 2.5mm ST segment depression, and these patients were referred for a coronary angiography. One pilot was found to have severe disease, one pilot had trivial disease and one pilot had normal coronary arteries. One of the four pilots with positive ECG results showed less than 1mm ST segment depression but was referred for a stress nucleotide scan on the recommendation of the NZCAA, which was normal. This patient was not then referred for coronary angiography.

A cross-tabulation of those who underwent stress electrocardiography followed by coronary angiography indicated that four pilots with severe disease on coronary angiograms were preceded with one positive, two borderline and one negative ECG. Moreover, among the six pilots with a positive or borderline stress ECG, three of them revealed severe disease, one showed a trivial disease and two had normal coronary arteries on their coronary angiograms.

Three patients underwent stress echocardiography because of borderline results from their exercise ECG (in two pilots) and a negative exercise ECG but an abnormal resting ECG (in one pilot), all of which were normal. Despite these normal results, all three pilots subsequently had coronary angiograms; two were found to have severe disease and the third had normal coronary arteries.

Two patients had a stress nucleotide scan. One case was due to borderline stress ECG result, and found to have a small/minor reversible apical defect. This was followed by a coronary angiography which showed a severe disease. Another pilot was referred to this examination due to a positive stress ECG and the result of the stress nucleotide scan was normal and he underwent no further investigations.

From the above cardiac investigations, it can be seen that there were nine patients who underwent a coronary angiography. In two cases this was because of symptoms, in three cases due to a positive exercise ECG test, and in two cases because of a normal stress echocardiography test following a borderline exercise ECG test. In the latter, one case was due to an abnormal nuclear perfusion scan following a borderline stress ECG test and one case because of a normal stress echocardiography test following a normal exercise stress ECG with an abnormal resting ECG. Two pilots (one who had a positive stress ECG test and another who had a normal stress echocardiogram following a borderline stress ECG test) were found to have normal coronary arteries. Two patients had trivial coronary artery atheroma, characterized by mild three vessel disease.

Five patients had lesions that were considered significant, characterized by more than a 70% stenosis or an occlusion in one or more arteries. The first patient underwent successful percutaneous coronary intervention (PCI), the second patient underwent PCI which was unsuccessful and hence followed by coronary artery bypass graft (CABG) 3 wk later. The third patient underwent CABG. The other two pilots were treated medically.

Fig. 1. Cardiovascular investigations of pilots with excessive cardiovascular risk. IHD = Ischemic Heart Disease; No exam = did not undergo any further cardiovascular testing.
as there were no large vessel flow limiting stenosis and no evidence of symptomatic reversible ischemia.

In addition, one pilot was admitted to a hospital with transient right hemiparesis and was found to have multiple acute infarcts on Magnetic Resonance Angiography. A Holter monitor was performed in one pilot with a history of paroxysmal atrial fibrillation. The result was normal sinus rhythm. Another pilot in this high risk group underwent a 24 h ambulatory blood pressure due to a high clinic blood pressure, and was found to have moderate-severe daytime and nocturnal hypertension.

In about 19-yr retrospective observation, from November 1992 to May 2011, among the 30 pilots with excessive risk score, 8 (27%) pilots experienced a cardiovascular event. The cardiovascular events consisted of 3 non-ST segment elevation myocardial infarctions (NSTEMI), 1 ST segment elevation myocardial infarction (STEMI), 1 unstable angina, 1 ischemic stroke, and 2 asymptomatic cases which were found to have severe diseases on their coronary angiograms. The length of time from identified as having an excessive risk score until the occurrence of a cardiovascular event in these 8 pilots ranged from 1 to 72 mo, with a median (IQR) of 48 (56) mo. All of those pilots returned to flight, 5 pilots after 6 mo, 3 pilots after 1 yr, and all were still flying at the time of the study.

**DISCUSSION**

A comparison of the prevalence of “excessive” CVD risk in different countries is limited by the many different CVD risk algorithm. Even the Framingham equations differ in risk factors and endpoints; some countries use cardiovascular disease risk, and some use coronary heart disease risk. The prevalence of airline pilot with excessive CVD risk scores in this study (3.5%) is similar to that found in other pilot populations. The application of the Framingham method in 614 pilots certified by the Colombian Civil Aeronautic Society indicated that the prevalence of those in the high risk group (20% or higher 10 yr risk) was 8%, of which 3.7% were found in class 1 certificate holders and 13.5% in class 2 certificate holders (2). Application of a nonlaboratory Framingham risk model among commercial pilots, who represented 56% of all Joint Aviation Authority Class 1 certificate holders in the UK, showed that 9.2% of all pilots had 10-yr absolute CVD risk greater than 20% (13). The difference in the prevalence from our study might be due to the difference in the risk factors incorporated in the risk assessment tool. However, the prevalence of high CVD risk in this study is lower than that in the general population. Assessment of CVD risk using the unadjusted Framingham risk chart indicated that 32.5% of patients aged between 35-64 yr attending primary care provider in New Zealand had 5-yr CVD risk of 10–15% risk or above; where the NZGG method adjustments increases the number of people classified as high risk by 48% (24). The higher prevalence in those studies, related to different characteristics and selection of the study population.

The comparison of CVD risk factor characteristics showed that all risk factors incorporated in the NZGG risk chart, including age, systolic blood pressure, total cholesterol – HDL ratio, diabetes status and smoking history, in high risk group were found higher than those in lower risk group. This finding emphasizes the importance of preventive measures focusing on those risk factors involved in the calculation of CVD risk score. In addition, almost one third of the high risk pilots received an adjustment, mainly due to having a family history of premature IHD. A population based study in New Zealand found that the adjustment increased the proportion of patients classified as 10–15% risk per 5 yr by 48% (24). Given the fact that a family history of premature IHD was associated with increased risk of a CVD event (6), this adjustment seemed to be effective in detecting those at high risk group. Different risk prediction models produce different CVD risk, but none of them may be very accurate (14). This study indicates that the NZGG model was able to increase the screening ability of CVD in airline pilot population from the basic Framingham method.

A study determining the usefulness of exercise ECG among asymptomatic men concluded that this test provided additional prognostic information in Framingham risk score models, especially among those with CVD risk of 20% per 10 yr or higher (3). A recent systematic review reported that abnormalities on exercise ECG in asymptomatic subjects, adjusted for traditional risk factors, were associated with an increased risk for subsequent cardiovascular events, although the clinical implications of the findings were unclear (5). However, the sensitivity and specificity of the exercise ECG in detecting severe diseases on coronary angiography were only 68% and 77%, respectively (4). In our study, half of pilots with a positive or borderline stress ECG revealed a normal result or trivial disease on their coronary angiograms and because 18 of the 19 pilots with a normal stress ECG did not undergo further investigations we cannot be sure how much true disease was missed by this approach.

In addition, although stress echocardiography is regarded as having high negative predictive value for primary and secondary cardiac events (17), in our study two of three high risk pilots with normal stress echocardiograms had severe disease on their coronary angiograms. Further, despite all three pilots having normal echocardiograms, they all subsequently had coronary angiograms. This indicates that in this group, the clinicians managing the patients did not have high confidence in the ability of this test to exclude significant disease.

Around 27% pilots with excessive CVD risk in our study experienced a CVD event. This may be compared to the general population where, 43.7% men aged 35-74 yr with 10% 5-yr CVD risk or above experienced a CVD event in the subsequent 5-yr period (18). The difficulty of accurately detecting cardiovascular risk in this population is further demonstrated by our previous observation that 47% of those with cardiovascular events never achieve a 10% 5 yr risk level using the current risk model (25).

Given the importance of preventing pilots from having sudden onset incapacitating cardiovascular events, the need exists for investigations that are better able to detect...
“silent” cardiovascular disease. It is possible that the addition of laboratory markers or the use of noninvasive imaging such as carotid-intima media thickness, calcium scoring or CT coronary angiography would enhance the ability to accurately detect this population, while at the same time reducing the number of pilots who are exposed to the risks of coronary angiography. For instance, a study in New Zealand found that approximately 10–27% of patients with a low CVD risk score as assessed by the NZGG risk chart have a markedly increased calcium score and hence are actually at a high cardiovascular risk (9). Further investigation of the potential benefits of these tools in pilot population is warranted.

The small number of observations in this study might affect how well these results can be generalized. The outcomes of this study may not be representative of all pilots with elevated risk scores at this airline. In particular, the pilots we studied are apparently the survivors, since they were still flying up to 19 yr after an elevated risk score was first identified. We did not have any information about the pilots over that same period of time who may have had elevated risk scores and subsequently died or been disqualified from flying because of cardiovascular disease. In addition, the analysis of this study was based on coronary angiography findings as the main outcome. Although severity of stenosis related to the risk of acute myocardial infarction (11), some researchers have suggested that vulnerability of coronary plaque may be playing a more important role than the degree of stenosis in coronary arteries (21,22). In this study, due to the small number of events, cardiovascular disease as the important patient’s outcomes could not be fully investigated, although some of the events have been presented descriptively.

This descriptive report adds valuable data on the extent of high CVD risk problems among airline pilot population. The results found in this study highlight the importance of primary prevention focusing on risk factors included in the risk assessment to reduce the risk of in-flight incapacitation from a cardiovascular event. In addition, this study indicates the need for a more comprehensive and accurate cardiac investigation algorithm for pilots with excessive CVD risk.

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