# Global Cardiovascular Risk and Associated Factors in 2792 French Military and Civilian Aircrew

Nicolas Huiban; Mélanie Gehant; François-Xavier Brocq; Fanny Collange; Aurélie Mayet; Marc Monteil

**INTRODUCTION:** Cardiovascular (CV) diseases are a major public health issue, the prevention of which plays a key role in promoting flight safety. However, few studies have looked at the determinants of the overall risk of CV morbidity-mortality within the various aeronautical occupations.

**METHODS:** A monocentric, observational, cross-sectional study was based on the retrospective data collected during 6 mo at the Toulon Aeromedical Center. From October 2017 to April 2018, 2792 professional aircrew ages 18–74 were included. The overall CV risk was estimated using the European Society of Cardiology SCORE and the Framingham model, as well as a summation model.

**RESULTS:** More than two-thirds of this mainly male population (86.2%) had no more than one CV risk factor [69.9% (68.2–71.6)]. In 82.5% of cases, this was dyslipidemia according to current European criteria [55.8% (52.4–59.1)] or smoking [26.7% (23.8-29.8)]. An overall risk level of "moderate" to "very high" concerned only one subject in five according to the SCORE model [20.1% (18.6-21.6)], one in six according to Framingham [16.3% (14.9-17.7)] and almost one in three according to the summation model [30.1% (28.4-31.9)].

**DISCUSSION:** Multivariate analyses found no significant associations between socio-professional criteria and overall risk levels. The results have underlined the effect of dyslipidemia and smoking on early risk among applicants. Beyond the illustration of favorable cardiovascular status among aircrews related to the standards of selection and close monitoring process, areas for improvement were identified, inviting the development of prevention strategies around the "moderate" overall CV risk.

**KEYWORDS:** risk factors, cardiovascular diseases, prevention, aircrew.

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Cardiovascular diseases (CVD) are the leading cause of death, morbidity, and disability worldwide.[9] Many publications derived from the Framingham Heart Study made it possible to retain a composite definition of these CVDs, dominated by coronary heart disease, cerebrovascular events (ischemic, hemorrhagic, and transient), peripheral arterial disease, and sudden death.[12] These studies have also unanimously validated the role of main risk factors (CVRF) among which hypertension (HBP), smoking, hypercholesterolemia, and diabetes are major so-called "modifiable" factors, in parallel with intrinsic ("non-modifiable") factors such as heredity, age, and gender.[4] In the specific environment of professional aviation, aircrew (both military and civilian) are legally assigned to close medical supervision to look for any pathological conditions likely to compromise the safe exercise of their license privileges. In this context, cardiovascular health occupies an essential place. While many European cohort studies have documented low cardiovascular mortality in aircrew compared to the general population, CVD remains the primary cause of in-flight sudden incapacitating medical events.[6] These represent

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one of the main causes of temporary or definitive loss of professional license in Western Europe. The cardiovascular system may also be particularly subjected to physiological constraints with incapacitating potential, which are imposed both by the hostile air environment (oxygen depletion, drop in barometric pressure, and temperature) and the operating mode of aircraft (accelerations, vibrations, sound environments, heat, drop in hygrometry). These are particularly significant in a military operational context.[17] Historically, the medical approach to flight safety was forged on a common cultural basis with technical risk management related to the advent of commercial aviation. The "absolute" risk based on the probability of in-flight incapacitating events has, therefore, gradually been taken into account and become a paradigm in parallel with the inseparable notion of "acceptable risk."[26] Different approaches have been proposed in the fitness decision process to determine the threshold of this acceptable risk. One of the most recent is based on a three-dimensional stratification matrix which integrates the probability of a medical event, its potential severity, and the duties performed in flight by aircrew.[10] Taking into account the workplace, specificities and the global dimension of risk should therefore now prevail. However, very few studies have been devoted to CVRF and the absolute CVD risk in aircrew, these often being limited to only commercial pilots.[11] Designing a new study, therefore, seemed an opportune time to address the vast field of cardiovascular risk in aircrew.

Two objectives were thus identified: to document global CV risk by looking for possible socio-professional determinants and to study the distribution of the main risk factors within this population. This second objective would make it possible to identify potential areas for improvement in current prevention strategies, with reference to French national data currently represented by two studies: ESTEBAN (étude de santé sur l'environnement, la biosurveillance, l'activité physique et la nutrition), conducted in 2014–2016,[20] and a previous ENNS survey (étude nationale nutrition santé) in 2006–2007.[5]

## METHODS

### Subjects

The inclusion criteria concerned all the aircrew population received for medical licensing by the Toulon Aeromedical Center (AeMC) between October 2017 and April 2018. The non-inclusion criteria grouped subjects under the age of 18 or over 74 yr. This sampling made it possible to recruit both a civilian and military population, as applicants or trained aircrew. Most often, depending on the aviation type and occupational duties, the regulatory validity period for licenses varies from 6 mo to 2 yr. An exhaustive 6-mo inclusion period was therefore conducive to recruiting a sample deemed representative of the aircrew population supervised by the Toulon AeMC. The occupational roles of aircrew included pilots, rear crew (airborne combat systems operator, flight engineers, airborne electronic sensor operators, flight test engineers), navigators, cabin crew (flight attendants and stewards), air traffic controllers (ATCO), paratroopers, and an Others category. This latter referred to military applicants for occupational categories not clearly defined as aircrew but strongly involved in flight safety (e.g., aircraft directors and flight deck officers on aircraft carriers). With the exception of navigators, the Others category (both strictly military), and cabin crew (only civilians), all roles were mixed. The study protocol was designed in compliance with the law on the protection of personal data according to a reference methodology published by the French National Commission for Informatics and Freedoms (CNIL). The strictly retrospective use of the data, without an intervention component, made it possible to classify this project outside "research involving the human person" according to the implementing decree no. 2016–1537 of November 16, 2016, of the law no. 20,125–300 of March 5, 2012 (known in France as the "Jardé law"). The project received a favorable ethics opinion from the clinical trials validation committee of the Sainte-Anne Military Hospital (Toulon) registered as an Institutional Review Board (No. IRB00011873-2020-01).

### Procedure

This was a single-center, observational, and cross-sectional study based on retrospective analysis of data from subjects included during 6 mo of Toulon AeMC activity. The data were gathered in an anonymous computer database created with Microsoft Excel 2010© and benefitted from advanced controls in order to limit entry errors. The measured variables corresponded to sociodemographic, biometric, and biological data and some CVRF. They included gender; age; aviation type (civilian or military); aircrew roles; license profile (applicant or trained aircrew); weight; height; body mass index (BMI); waist circumference (WC); systolic blood pressure (SBP); diastolic blood pressure (DBP); smoking; taking lipid-lowering, antihypertensive, or antidiabetic therapy; a medical history of diabetes or obstructive sleep apnea syndrome (OSAS); cardiovascular prevention status (primary or secondary); total cholesterolemia (TC); low density lipoprotein (LDL-c), high density (HDL-c) lipoprotein, and triglycerides (TG); and fasting blood glucose (FBG).

Age was defined as a risk factor from 50 yr old for men and 60 yr old for women. Automated blood pressure measurement was verified by experienced AeMC nurses. In the event of values greater than 140/90 mmHg, a check after 20 min of lying down was systematically carried out. HBP was defined as SBP ≥ 140 mmHg and/or DBP ≥ 90 mmHg or taking antihypertensive therapy. Weight and height were systematically measured and BMI calculated (weight/height$^2$ in $kg \cdot m^{-2}$). Obesity was defined as a BMI ≥ 30 $kg \cdot m^{-2}$. As tobacco consumption was systematically assessed by a regulatory questionnaire, people could be classified as active smokers (or weaned for less than 3 yr) and non- or ex-smokers. Dyslipidemia was defined on the basis of the latest recommendations from the European Society of Cardiology (ESC 2019).[15] It was thus defined as LDL-c ≥ 1.16 $g \cdot L^{-1}$ for a low Systematic Coronary Risk Evaluation (SCORE) risk, LDL-c ≥ 1.0 $g \cdot L^{-1}$ in the event of a moderate SCORE risk, LDL -c ≥ 0.7 $g \cdot L^{-1}$ for a high SCORE risk, LDL-c ≥ 0.55 $g \cdot L^{-1}$

for a very high SCORE risk, or, finally, in case of lipid-lowering treatment with statin (as monotherapy or in combination). Prediabetes was defined by World Health Organization (WHO) criteria in case of FBG $\geq 1.10\,g \cdot L^{-1}$. International Diabetes Federation criteria (IDF 2005) were used to define metabolic syndrome in the presence of a WC $\geq$ 94 cm (men) or 80 cm (women), associated with at least two factors among: blood pressure $\geq$ 130/85 mmHg; HDL-c $< 0.4\,g \cdot L^{-1}$ (men) or $< 0.5\,g \cdot L^{-1}$ (women); triglycerides $\geq 1.5\,g \cdot L^{-1}$; or FBG $\geq 1.0\,g \cdot L^{-1}$. Finally, people with an established diagnosis of diabetes, OSAS, or being treated with secondary prevention measures after a CVD event were identified by a systematic and documented analysis of their medical file. From these collected data, supplementary variables were derived in order to assess the individual global cardiovascular (CV) risk according to three parameters: the total number of CVRF, the estimated 10-yr CVD risk, and the risk levels categorization using different selected models. The SCORE model offered the advantage of having been developed from European cohorts and of being applied to countries with low incidence rates of CVD, including France. On the other hand, it only estimates a 10-yr cardiovascular mortality risk based on five CVRF: gender, age, SBP, TC, and smoking.[3] The Framingham model, as updated by D'Agostino et al. in 2008, is one of the most used over the world. Despite a tendency to overestimation noted in the absence of recalibration for European countries,[16] it makes it possible to assess a global 10-yr risk of cardiovascular morbidity and mortality. This model was, therefore, particularly suited to aviation medicine and the challenge of assessing a risk of incapacitating in-flight events. Retained CVRF are gender, age, SBP, taking antihypertensive medication, HDL-c levels, smoking, and diabetes. Finally, a third older model based on the summation of CVRF was inspired by an approach proposed in 2005 by the French Haute Autorité de Santé in recommendations (now updated) about the management of essential hypertension in France. In comparison with previous prediction models using a mathematical equation of combined factors, this type of approach exposes the pitfall of a global overestimation without capacity to provide a quantified, precise, and reproducible estimated risk. Nevertheless, this third strategy offered the possibility of taking into account both classic CVRF (age, dyslipidemia, hypertension, smoking, diabetes) and other supplementary factors such as obesity, metabolic syndrome, prediabetes, or even OSAS in the stratification of an absolute CV risk. The 10-yr CVD individual probabilities have been calculated using online resources (http://www.cardiorisk.fr). Risk levels were defined as low (SCORE < 1%, Framingham < 10%), moderate (1% ≤ SCORE < 5%, 10% ≤ Framingham < 20%), or high (SCORE ≥ 5%, Framingham ≥ 20%). The very high risk level was reserved in cases of previously documented CVD. For the summation model, a risk matrix was used, classifying diabetic people straight away at a high risk level (**Fig. 1**). Whatever the model used, primary outcomes were defined by a risk level from moderate to very high and by the presence of at least one CVRF in applicants. Secondary outcomes were represented by all collected CVRF: age, dyslipidemia, HBP, smoking, obesity, (pre)diabetes, metabolic syndrome, and OSAS.

### Statistical Analysis

The statistical analysis first included univariate study of the global CV risk parameters distribution according to sociodemographic data. Comparison tests were retained according to the variables (quantitative or qualitative) and the application rules for parametric tests. Bivariate analyses between qualitative variables were thus based on the Chi-squared or Fisher's exact tests. Those between qualitative and quantitative variables were based on the Student or Wilcoxon tests (for comparisons between two groups), and the analysis of variance (ANOVA) or Kruskall-Wallis test was used for comparisons including more than two groups. In cases of multiple pairwise comparisons or post hoc test for categorical variables with several modalities (e.g., age groups or aircrew roles), adjusting methods (Holm or Bonferroni) for the *P*-value analysis were used. Multivariate analysis by linear or logistic regressions models then made it possible to study associations between variables after adjustment for confounding factors, in particular age and gender. Primary and secondary outcomes were included as dependent variables in these models. Missing data were collected for biometrics in negligible proportions (less than 1% for all variables). On the other hand, for the biological results, these proportions could reach 17% due to partial blood examinations prescribed for people under 40 yr of age and, therefore, significantly limit the 10-yr global CV risk estimation as well as the ability to properly define some CVRF. This dependence on age, defined as a complete explicative variable, made it possible to classify these missing data as "missing at random" (MAR) according to the classification of Little and Rubin.[28] It was then possible to consider a

| | Blood pressure (mmHg) | | | |
|---|---|---|---|---|
| **Number of CVRF** | **Normal (<140/90)** | **140-159/90-99** | **160-179/100-109** | **≥ 180/110** |
| **0** | Low | Low | Moderate | High |
| **1** | Low | Moderate | Moderate | High |
| **2** | Moderate | Moderate | Moderate | High |
| **3 (and more)** | High | High | High | High |
| **Cardiovascular disease** | Very high | Very high | Very high | Very high |

**Fig. 1.** Matrix of cardiovascular risk levels used for the summation model (adapted from the HAS 2005 recommendations about the management of adults with essential hypertension in France).

treatment based on multiple imputations by chained equations in order to exploit all collected parameters. The number of iterations was fixed by the percentage of missing data per variable, the latter not exceeding 30%. The derived variables could be directly deduced, without themselves being concerned by imputations. All the statistical analyses were carried out with R© software (Version 1.1.456; The R Foundation, Vienna, Austria). The MICE package (version 3.6.0; The R Foundation) was used to deal with the missing data.

## RESULTS

Of the 2822 aircrew involved in a licensing medical visit during the study period, 2792 were included. The population was predominantly male (86.2%) and military (52.5%), and the mean age was 38.5 yr (SD 12.4). Military airmen were younger than civilians (32.8 yr vs. 44.9 yr, $P < 0.001$). Almost two-thirds of aircrew were pilots [61.2% (59.4–63.1)]. Almost one in six people (16.0%) applied for a first professional license. Applicants were younger [24.4 yr (23.8–24.9)] than trained crew [41.2 yr (40.7–41.7), $P < 0.001$] and, more than 8 times out of 10, were applying for a military career [81.2% (77.3–84.7)].

Only 22 subjects had a past history of CVD (coronary or cerebrovascular disease), i.e., 0.8% (0.5–1.2) of the population. They were all men. Their mean age was 51.6 yr (48.5–54.7), with no significant difference from the mean age of people at a moderate risk level defined by SCORE [54.7 yr (54.3–55.1), $P = 0.17$] or Framingham [53.8 yr (53.2–54.4), $P = 0.33$]. According to the summation model, this mean age was not significantly different between subjects at a moderate risk level [48.0 yr (47.1–48.9), $P = 0.20$] or at a high risk level [52.8 yr (51.7–53.9), $P = 0.60$].

This secondary prevention group comprised 13 military and 9 civilian subjects, including 11 pilots, 8 rear crew, and 3 ATCO. Biometrically, they were on average slightly overweight [mean BMI = 26.1 $kg \cdot m^{-2}$ (24.7–27.4)] with a waist circumference of 93.7 cm (89.8–97.6), reflecting excess central adiposity. Their mean blood pressure was 129.4 mmHg for SBP (123.8–134.9) and 76.9 mmHg for DBP (72.4–81.4), while 54.5% (32.2–75.6) were taking antihypertensive therapy. Biologically, their mean lipid levels were 1.66 $g \cdot L^{-1}$ (1.52–1.81) for TC, 0.90 $g \cdot L^{-1}$ (0.78–1.03) for LDL-c, 0.52 $g \cdot L^{-1}$ (0.47–0.58) for HDL-c, and 1.08 $g \cdot L^{-1}$ (0.90–1.25) for TG. These results were achieved with lipid-lowering treatment in 81.8% (59.7–94.8) of cases. Mean FBG was 0.99 $g \cdot L^{-1}$ (0.95–1.02), significantly higher than the rest of the study population if based on the 95% confidence intervals. According to WHO criteria, 10 subjects (45.5%) had prediabetes. In terms of risk factors, this sample presented an average of 3.4 risk factors per subject, including five smokers (active or weaned for less than 3 yr), six cases of metabolic syndrome, and one case of OSAS. Unfortunately, the study protocol did not allow for the collection of risk factors prior to the diagnosis of cardiovascular disease in this secondary prevention group. More than two-thirds of the population had at most only one CVRF [69.9% (68.2–71.6)]. In 82.5% of cases, this corresponded to dyslipidemia [55.8% (52.4–59.1)] or smoking [26.7% (23.8–29.8)] (**Fig. 2**). The mean number of CVRF increased with age ($P < 0.001$). It was higher in men than in women [1.19 (1.14–1.25) vs. 0.61 (0.53–0.70), $P < 0.001$] (**Table I**).

After adjusting for age and gender, this number was found to be identical between civilians and military personnel ($P = 0.45$). It was significantly unfavorable for two professional categories. That observed among controllers was higher than that of pilots [+0.39 factors (0.20–0.57), $P < 0.001$], cabin crew [+0.40 factors (0.14–0.66), $P < 0.001$], and paratroopers[+0.60 factors (0.16–1.04), $P < 0.01$], while that of rear crew was higher than that of pilots [+0.22 factors (0.07–0.38), $P < 0.001$] and paratroopers [+0.44 factors (0.01–0.87), $P < 0.05$] (**Fig. 3A**).

In applicants, this mean number of CVRF was significantly higher than that documented among trained crew [+0.40 (0.29–0.51), $P < 0.001$]. In the presence of at least one risk factor, 51.7% (44.0–59.4) of the applicants were dyslipidemic and 48.3% (40.6–46.0) were smokers. The 10-yr global risk of CVD was estimated at 0.58% (0.54–0.62) for SCORE and 5.16% (4.93–5.38) according to Framingham. This risk was thus defined as low for the entire population studied. The two models had an excellent correlation between them [Pearson coefficient calculated at 0.89 (0.88–0.89), $P < 0.001$]. These values were higher in men than in women: respectively, 0.65% (0.61–0.69) vs. 0.14% (0.11–0.17) ($P < 0.001$) for SCORE, 63% (5.38–5.89) vs. 2.22% (1.96–2.48) ($P < 0.001$) for Framingham. Both scores increased with age ($P < 0.001$) (Table I). After adjusting for age and gender, the estimates were identical between civilians and military personnel ($P = 0.35$ for SCORE and $P = 0.43$ for Framingham). The comparison of the global risk between the professional categories was most often to the benefit of the cabin crew. Their risk according to SCORE was indeed significantly lower than that of pilots [−0.41% (0.25–0.57), $P < 0.001$], controllers [−0.31% (0.01–0.60), $P < 0.05$], navigators [−0.34% (0.06–0.63), $P < 0.01$], and rear crew [−0.38% (0.20–0, 56), $P < 0.001$] (**Fig. 3B**). Their risk according to Framingham was also lower than that of pilots [−1.34% (0.41–2.27), $P < 0.001$], controllers [−1.72% (0.67–2.78), $P < 0.001$], and rear crew [−1.50% (0.45–2.54), $P < 0.001$] (**Fig. 3C**).

In addition, applicants presented a global risk significantly higher than that documented among trained aircrew: +0.45% (0.37–0.53) for SCORE ($P < 0.001$) and +1.72% (1.27–2.17) for Framingham ($P < 0.001$). Those with at least one CVRF had a Framingham risk 0.42% (0.21–0.63) higher than that of the other applicants ($P < 0.001$). In contrast, the SCORE risk was not significantly different between these two groups ($P = 0.49$).

A global risk level from moderate to very high was shown in one in five subjects according to the SCORE model [20.1% (18.6–21.6)], one in six subjects according to Framingham [16.3% (14.9–17.7)], and nearly one in three subjects according to the summation model [30.1% (28.4–31.9)]. Regardless of the model used, these proportions were higher in men than in women ($P < 0.001$) and increased with age ($P < 0.001$) (Table I).

After adjusting for age and gender, these proportions were identical between military and civilian personnel, whatever the

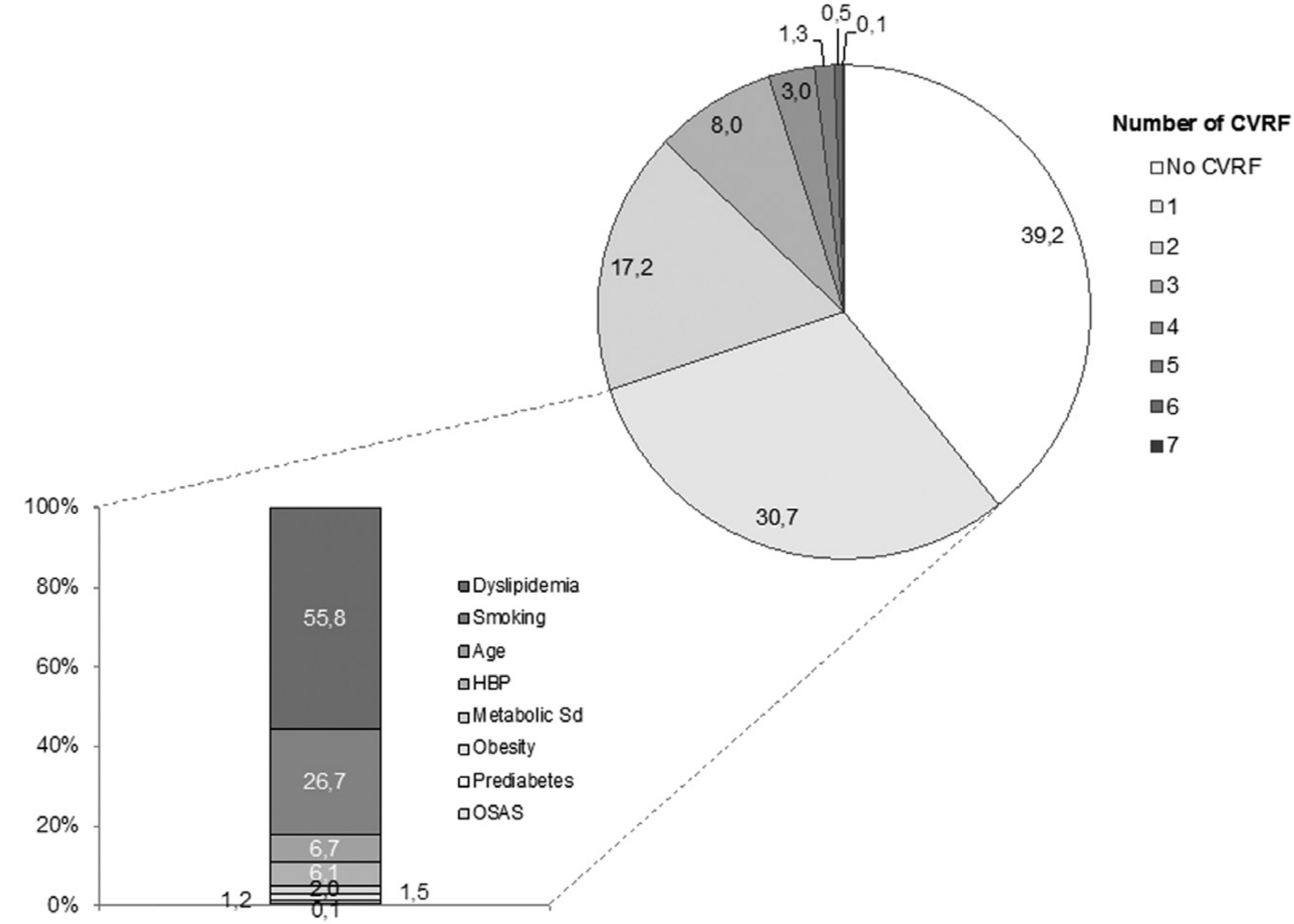


**Fig. 2.** Distribution of the number of CVRF and relative frequencies (in percentages) in a case of a single CVRF.

model used. After post hoc comparisons between professional categories, the proportions for the SCORE risk were identical. For the Framingham risk, the only significant difference concerned the controllers, with a higher proportion than that observed among the pilots ($P < 0.05$). The summation model found this same difference to the detriment of the controllers ($P < 0.001$) as well as the rear crew ($P < 0.05$). On the other hand, only this last model documented a higher proportion of risk level from moderate to very high in applicants than among trained aircrew {OR = 3.75 (2.45–5.71), $P < 0.001$]. Regardless of the model used, the proportion of risk observed in applicants with at least one risk factor was not different from that of the other applicants ($P = 0.99$).

The CVRF distribution according to sociodemographic data and global risk parameters is presented in **Table II**. The results of multivariate analyses by logistic regression models are presented in **Table III**.

The prevalence of dyslipidemia was 44.6% (42.8–46.5), with an overall tendency to increase with age ($P < 0.001$). Men were more affected than women (47.3% vs. 27.7%, $P < 0.001$). Dyslipidemic people had a mean number of CVRF of 2.06 (1.99–2.12) vs. 0.35 (0.32–0.39) if there was no lipid metabolism disorder ($P < 0.001$) (Table II). In multivariate analysis, controllers [OR = 1.56 (1.12–2.18), $P < 0.01$] and rear crew [OR = 1.44 (1.09–1.89), $P < 0.01$] duties were positively and significantly associated with the risk of dyslipidemia compared to pilots (reference), while military status was protective [OR = 0.76 (0.61–0.96), $P < 0.05$]. Among other risk factors, hypertension [OR = 1.72 (1.27–2.33), $P < 0.001$] and the presence of OSAS and/or metabolic syndrome [OR = 2, 02 (1.40–2.94), $P < 0.001$] were also significantly associated with the risk of dyslipidemia (Table III).

The prevalence of HBP was 12.4% (11.2–13.7) [13.8% (12.4–15.2) in men and 3.9% (2.2–6.3) in women, $P < 0.001$]. It increased significantly with age, from 4.9% in 18–34 yr olds to 63.2% in 65–74 yr olds ($P < 0.001$). The prevalence in men was higher than women for all age groups. People with HBP presented on average 2.96 (2.81–3.10) CVRF against 0.85 (0.82–0.89) in normotensive subjects ($P < 0.001$) with, in almost a third of cases, associated OSAS and/or metabolic syndrome [31.7% (26.8–36.9)] (Table II). In multivariate analysis, regardless of age and gender, ATCO duties [OR = 1.91 (1.22–2.96), $P < 0.01$] were positively and significantly associated with the risk of HBP vs. pilots (reference). Among the other risk factors, dyslipidemia [OR = 1.74 (1.29–2.37), $P < 0.001$], obesity [OR = 2.37 (1.54–3.60), $P < 0.001$], and the presence of OSAS and/or metabolic syndrome [OR = 3.12 (2.24–4.34), $P < 0.001$] were also associated with the risk of HBP (Table III).

**Table I.** Distribution of Parameters for Global Cardiovascular Risk According to Sociodemographic Data.

| | | | 10-YR CV RISK | | | | RISK LEVELS FROM "MODERATE" TO "VERY HIGH" (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NUMBER OF CVRF | | SCORE | | FRAMINGHAM | | SCORE | | FRAMINGHAM | | SUMMATION | |
| **SOCIODEMOGRAPHIC** | **MEAN** | **CI 95%** | **MEAN** | **CI 95%** | **MEAN** | **CI 95%** | **%** | **CI 95%** | **%** | **CI 95%** | **%** | **CI 95%** |
| Global population | 1.11 | 1.07–1.16 | 0.58 | 0.54–0.62 | 5.16 | 4.93–5.38 | 20.1 | 18.6–21.6 | 1.3 | 14.9–17.7 | 30.1 | 28.4–31.9 |
| Gender | | | | | | | | | | | | |
| Males | 1.19 | 1.14–1.25 | 0.65 | 0.61–0.69 | 5.63 | 5.38–5.89 | 23.1 | 21.4–24.8 | 18.6 | 17.0–20.2 | 33.0 | 31.1–34.9 |
| Females | 0.61 | 0.53–0.70 | 0.14 | 0.11–0.17 | 2.22 | 1.96–2.48 | 1.6 | 0.6–3.4 | 1.8 | 0.7–3.7 | 12.2 | 9.1–15.9 |
| *P*-value | *** | | *** | | *** | | *** | | *** | | *** | |
| Age groups (yr) | | | | | | | | | | | | |
| 18–34 | 0.47 | 0.43–0.50 | 0.03 | 0.02–0.03 | 1.22 | 1.16–1.28 | 0.1 | 0.0–0.5 | 0.2 | 0.0–0.6 | 7.9 | 6.5–9.6 |
| 35–44 | 0.87 | 0.80–0.95 | 0.23 | 0.21–0.24 | 3.90 | 3.68–4.11 | 1.0 | 0.4–2.1 | 4.2 | 2.8–6.1 | 18.9 | 15.9–22.2 |
| 45–54 | 1.72 | 1.63–1.82 | 0.93 | 0.88–0.97 | 8.45 | 8.09–8.81 | 39.4 | 35.9–43.1 | 28.0 | 24.8–31.4 | 51.4 | 47.7–55.1 |
| 55–64 | 2.74 | 2.60–2.88 | 2.56 | 2.40–2.72 | 15.18 | 14.27–16.08 | 96.9 | 94.0–98.6 | 79.4 | 73.9–84.2 | 93.0 | 89.2–95.8 |
| 65–74 | 3.79 | 3.14–4.44 | 5.98 | 5.06–6.91 | 27.61 | 22.00–33.21 | 100 | 82.4–100 | 100 | 82.4–100 | 100 | 82.4–100 |
| *P*-value | *** | | *** | | *** | | *** | | *** | | *** | |
| Aircrew roles | | | | | | | | | | | | |
| Pilots | 1.14 | 1.08–1.20 | 0.70 | 0.65–0.76 | 5.73 | 5.42–6.04 | 25.6 | 23.6–27.8 | 19.7 | 17.8–21.7 | 32.5 | 30.3–34.8 |
| Rear crew | 1.09 | 0.97–1.22 | 0.42 | 0.35–0.50 | 4.32 | 3.78–4.85 | 13.8 | 10.6–17.6 | 11.9 | 8.9–15.4 | 27.2 | 22.9–31.8 |
| ATCO | 1.32 | 1.15–1.49 | 0.46 | 0.35–0.56 | 5.05 | 4.35–5.75 | 15.8 | 11.6–20.7 | 15.4 | 11.3–20.3 | 32.3 | 26.7–38.3 |
| Cabin crew | 0.93 | 0.81–1.06 | 0.30 | 0.24–0.36 | 3.77 | 3.31–4.23 | 5.7 | 3.3–9.3 | 7.3 | 4.4–11.1 | 22.2 | 17.3–27.8 |
| Navigators | 0.69 | 0.49–0.88 | 0.17 | 0.10–0.24 | 2.50 | 1.90–3.10 | 4.3 | 0.9–12.0 | 2.9 | 0.3–9.9 | 12.9 | 6.1–23.0 |
| Paratroopers | 1.00 | 0.74–1.26 | 0.46 | 0.22–0.70 | 4.86 | 3.75–5.96 | 10.6 | 3.5–23.1 | 10.6 | 3.5–23.1 | 28.3 | 16.0–43.5 |
| Others | 1.04 | 0.65–1.43 | 0.19 | 0.04–0.34 | 3.22 | 1.99–4.44 | 3.8 | 0.1–19.6 | 3.8 | 0.1–19.6 | 26.9 | 11.6–47.8 |
| *P*-value | *** | | *** | | *** | | *** | | *** | | *** | |
| Aviation type | | | | | | | | | | | | |
| Civilian | 1.46 | 1.39–1.53 | 0.94 | 0.87–1.01 | 7.36 | 6.98–7.75 | 33.6 | 31.1–36.2 | 26.2 | 23.8–28.6 | 43.1 | 40.4–45.8 |
| Military | 0.80 | 0.75–0.86 | 0.25 | 0.23–0.28 | 3.16 | 2.96–3.36 | 7.9 | 6.6–9.4 | 7.4 | 6.1–8.8 | 18.6 | 16.4–20.4 |
| *P*-value | *** | | *** | | *** | | *** | | *** | | *** | |
| License profile | | | | | | | | | | | | |
| Applicants | 0.52 | 0.45–0.59 | 0.04 | 0.02–0.06 | 1.16 | 1.00–1.30 | 0.4 | 0.1–1.6 | 0.4 | 0.1–1.6 | 10.7 | 8.0–14.0 |
| Trained aircrew | 1.23 | 1.18–1.28 | 0.68 | 0.64–0.72 | 5.92 | 5.67–6.17 | 23.8 | 22.1–25.6 | 19.3 | 17.7–20.9 | 33.8 | 31.9–35.8 |
| *P*-value | *** | | *** | | *** | | *** | | *** | | *** | |

CVRF: cardiovascular risk factors; CV: cardiovascular; CI: confidence interval; ATCO: air traffic control officer.
Values are expressed as means and percentages; values in square brackets correspond to 95% confidence intervals.
***$P < 0.001$.

Tobacco consumption, current or weaned for less than 3 yr, affected 17.4% (16.1–18.9) of the population, without significant differences between age groups. Women smoked more than men (22.5% vs. 16.6%, $P < 0.01$). Smokers had a mean number of risk factors of 1.95 (1.85–2.06) compared to 0.94 (0.89–0.98) in non- or ex- smokers ($P < 0.001$). Almost one in two smokers was also dyslipidemic [46.4% (41.9–50.9)] (Table II). In multivariate analysis, gender was no longer a factor significantly associated with tobacco consumption. On the other hand, all professional categories, with the exception of navigators, were significantly associated with a higher probability of exposure to tobacco than that of pilots (reference): rear crew [OR = 2.32 (1.73–3.11), $P < 0.001$], controllers [OR = 2.81 (1.98–3.96), $P < 0.001$], cabin crew [OR = 3.39 (2.24–5.13), $P < 0.001$], paratroopers [OR = 2.09 (0.99–4.09), $P < 0.05$], and Other [OR = 4.85 (2.07–10.9), $P < 0.001$]. Military status was associated with a lower likelihood of smoking [OR = 0.70 (0.53–0.92), $P < 0.05$] while the presence of OSAS and/or metabolic syndrome was significantly associated with smoking [OR = 1.45 (1.00–2.08), $P < 0.05$] (Table III).

More than a third of the population [38.3% (36.5–40.2)] was overweight or obese. This involved 41.5% (39.5–43.5) of men and 18.7% (14.9–22.9) of women (significant difference according to sex: $P < 0.001$). The prevalence of obesity was 4.8% (4.0–5.7), higher in men than in women [5.2% (4.3–6.1) vs. 2.6% (1.2–4.7), $P < 0.05$] (Table II). Almost 9 in 10 obese subjects [86.6% (79.6–91.8)] presented with so-called moderate obesity ($30 \leq \text{BMI} < 35\,\text{kg} \cdot \text{m}^{-2}$).

In multivariate analysis, gender was not an independent risk factor for obesity ($P = 0.69$). On the other hand, ATCO duties were significantly associated [OR = 2.08 (1.11–3.83), $P < 0.05$] with the probability of obesity greater than that of pilots (reference) while dyslipidemia [OR = 1.65 (1.02–2.72), $P < 0.05$], HBP [OR = 2.32 (1.51–3.55), $P < 0.001$], and OSAS and/or metabolic syndrome [OR = 6.02 (3.91–9.27), $P < 0.001$] were significantly associated with obesity (Table III).

In total, 3.0% (2.4–3.8) of the population had diabetes or prediabetes. These patients had a mean number of risk factors of 3.72 (3.33–4.10) vs. 1.03 (0.99–1.08) ($P < 0.001$) if there were no glucose metabolism disorders. Dyslipidemia was associated in 70.6% (59.7–80.0) of cases (Table II).

Due to the small number of diabetic people, diabetes and prediabetes criteria were combined to perform multivariate analyses. Thus, ATCO duties were, in comparison with pilots (reference), an independent risk factor for diabetes or prediabetes [OR = 2.34 (1.09–4.91), $P < 0.05$]; likewise with the

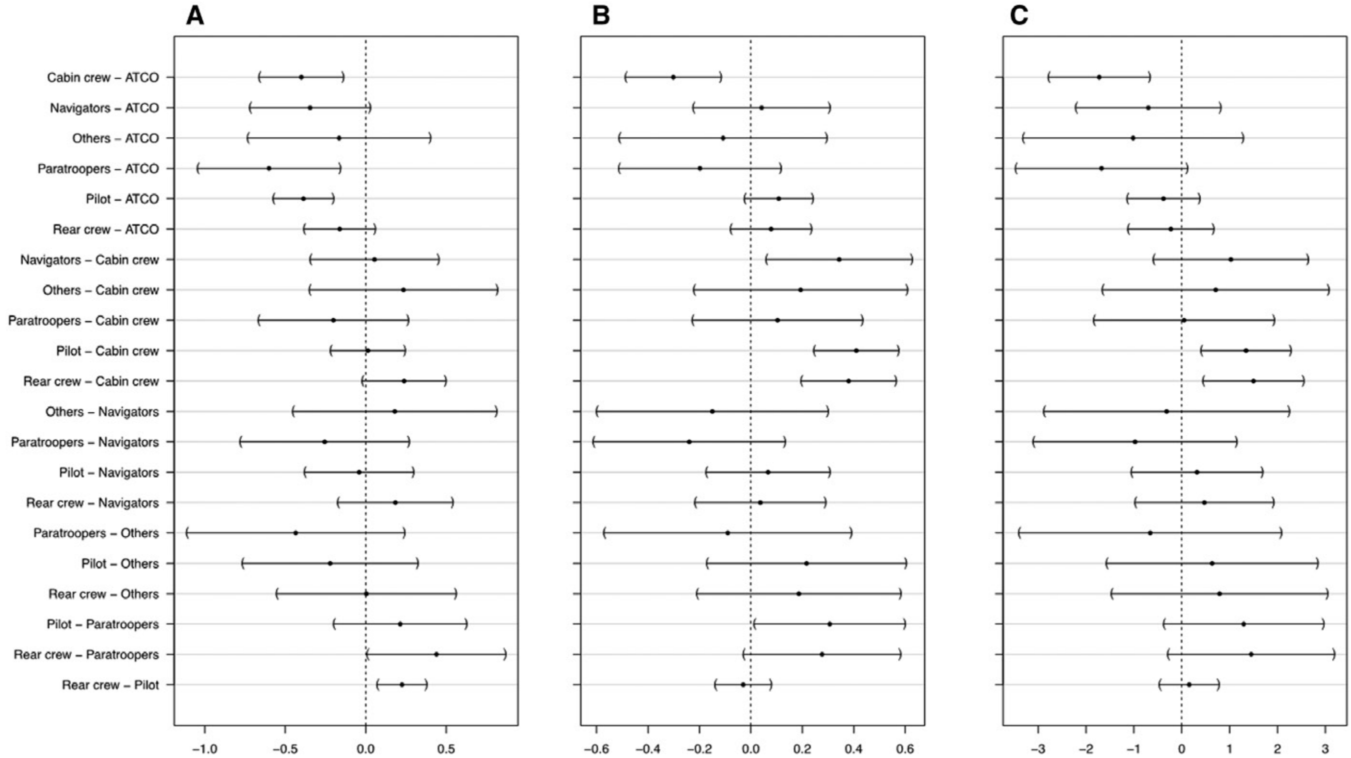


**Fig. 3.** Mean differences (with 95% confidence intervals) identified between the pairwised compared aircrew roles after adjustment for age and gender (linear regression), A) according to the number of CVRF; B) the SCORE risk; and C) the Framingham risk.

presence of OSAS and/or metabolic syndrome [OR = 7.57 (4.43–13.05), $P < 0.001$] (Table III).

The prevalence of metabolic syndrome was 9.1% (8.1–10.3). It was significantly higher in men than in women [10.1% (8.9–11.4) vs. 3.1% (1.6–5.4), $P < 0.001$], with a tendency to age-related increase ($P < 0.001$). Only 10 cases of OSAS, diagnosed and treated, were collected [0.4% (0.2–0.7)], with no difference related to gender ($P > 0.99$). After post hoc comparisons between age groups, no difference was retained as significant ($P > 0.20$). Patients with OSAS and/or metabolic syndrome had a mean number of risk factors of 3.39 (3.22–3.55) vs. 0.88 (0.85–0.92) for patients without ($P < 0.001$). Almost 8 times out of 10 [79.2% (73.7–83.9)], dyslipidemia was associated (Table II) with higher risk. The small number of patients with OSAS led to grouping with metabolic syndrome to perform multivariate analyses on the documented basis of a very frequent pathophysiological association.[8] Risk factors sharing a common field of definition with metabolic syndrome were thus significantly associated with it: dyslipidemia [2.08 (1.44–3.04), $P < 0.001$], HBP [OR = 3.14 (2.25–4.37), $P < 0.001$], obesity [OR = 6.11 (3.95–9.44), $P < 0.001$], and diabetes or prediabetes [OR = 8.10 (4.65–14, 15), $P < 0.001$] (Table III).

## DISCUSSION

The distribution by age groups shows a gradual attrition of aircrews. The majority of the population studied was military. They are significantly younger than civilians and have shorter careers in aviation, at the end of which retraining in the civil aviation sector is not systematic. At the same time, the oldest crews are those whose state of health remains compatible with the pursuit of aeronautical activities. This implies a better medical (in general) and cardiovascular (in particular) condition than other people of the same age who have interrupted their aeronautical career by choice (retirement) or for medical reasons (unfitness, with a high statistical representation of cardiovascular disease, as mentioned above[17]).

The prevalence of CVD in our sample was nearly 10 times lower than that of the French general population (0.8% vs. 7.6%).[25] The estimated probabilities of cardiovascular morbidity and mortality were generally low and, according to the validated models, our results seemed both consistent and better than in the general population, even after adjusting for the targeted age groups (40–65 yr for SCORE and 30–74 yr for Framingham).

In France, a survey about the evolution of cardiovascular risk and coronary mortality in the urban community of Lille found a SCORE risk of 2.2% in men and 0.7% in women among the 1636 ELISABET study participants over the period 2011–2013.[2] In the same age groups, the results obtained among aircrew were 1.24% (1.18–1.30) for men and 0.30% (0.23–0.37) for women. On a French national level, the study of 50,856 volunteers from the CONSTANCES cohort reported a global median SCORE risk of 0.9% (0.3–2.1) [1.7% (0.8–3.2) in men and 0.5% (0.2–1.2) in women]. Based on the 95% confidence intervals, our results were not significantly different: the median was 0.95% (0.90–1.00) [1.05% (1.0–1.10) in men and 0.25%

**Table II.** Distribution of Cardiovascular Risk Factors Based on Sociodemographic Data and Global Cardiovascular Risk Parameters.

| SOCIODEMOGRAPHIC/ RISK PARAMETER | CARDIOVASCULAR RISK FACTORS | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DYSLIPIDEMIA | | AGE | | SMOKING | | HBP | | OBESITY | | DIABETES OR PREDIABETES | | OSAS AND/OR METABOLIC SYNDROME | |
| | % | CI 95 | % | CI 95 | % | CI 95 | % | CI 95 | % | CI 95 | % | CI 95 | % | CI 95 |
| Global population | 44.6 | 42.8–46.5 | 19.4 | 18.0–21.0 | 17.4 | 16.1–18.9 | 12.4 | 11.2–13.7 | 4.8 | 4.0–5.7 | 3.0 | 2.4–3.8 | 9.3 | 8.2–10.4 |
| Gender | | | | | | | | | | | | | | |
| Males | 47.3 | 45.3–49.4 | 22.5 | 20.9–24.2 | 16.6 | 15.2–18.2 | 13.8 | 12.4–15.2 | 5.2 | 4.3–6.1 | 3.4 | 2.7–4.2 | 10.2 | 9.0–11.5 |
| Females | 27.7 | 23.3–32.5 | 0.3 | 0.0–1.4 | 22.5 | 18.5–27.0 | 3.9 | 2.2–6.3 | 2.6 | 1.2–4.7 | 1.0 | 0.2–2.3 | 3.4 | 1.8–5.7 |
| *P*-value | *** | | *** | | ** | | *** | | * | | ** | | *** | |
| Age groups (yr) | | | | | | | | | | | | | | |
| 18–34 | 18.9 | 16.7–21.2 | 0 | - | 17.7 | 15.5–20.0 | 4.9 | 3.8–6.4 | 1.7 | 1.0–2.6 | 1.2 | 0.7–2.0 | 2.1 | 1.4–3.1 |
| 35–44 | 44.4 | 40.5–48.4 | 0 | - | 19.7 | 16.6–23.1 | 8.4 | 6.3–10.9 | 4.0 | 2.6–5.9 | 1.8 | 0.9–3.2 | 8.9 | 6.8–11.4 |
| 45–54 | 69.4 | 65.9–72.7 | 37.7 | 34.1–41.3 | 16.7 | 14.0–19.6 | 20.4 | 17.5–23.5 | 7.6 | 5.8–9.8 | 4.4 | 3.0–6.2 | 15.3 | 12.8–18.1 |
| 55–64 | 88.7 | 84.2–92.3 | 97.7 | 95.0–99.1 | 14.0 | 10.0–18.9 | 30.0 | 24.4–36.0 | 11.3 | 7.7–15.8 | 9.3 | 6.1–13.6 | 22.2 | 17.3–27.8 |
| 65–74 | 100 | 82.4–100 | 100 | - | 5.3 | 0.1–26.0 | 63.2 | 38.4–83.7 | 26.3 | 9.1–51.2 | 21.1 | 6.1–45.6 | 57.9 | 33.5–79.7 |
| *P*-value | *** | | | | NS | | *** | | *** | | *** | | *** | |
| Aircrew roles | | | | | | | | | | | | | | |
| Pilots | 46.2 | 43.8–48.6 | 25.6 | 23.5–27.7 | 12.3 | 10.8–14.0 | 13.0 | 11.5–14.7 | 4.6 | 3.7–5.7 | 2.7 | 2.0–3.6 | 9.1 | 7.7–10.5 |
| Rear crew | 42.0 | 37.2–46.9 | 13.6 | 10.4–17.3 | 23.1 | 19.1–27.4 | 12.6 | 9.6–16.2 | 3.6 | 2.1–5.9 | 4.1 | 2.4–6.5 | 10.0 | 7.2–13.3 |
| ATCO | 46.6 | 40.5–52.8 | 11.7 | 8.1–16.1 | 25.6 | 20.4–31.2 | 16.9 | 12.6–22.0 | 9.4 | 6.2–13.6 | 6.0 | 3.5–9.6 | 14.3 | 10.3–19.1 |
| Cabin crew | 38.3 | 32.4–44.5 | 4.6 | 2.4–7.9 | 30.7 | 25.5–36.6 | 7.3 | 4.4–11.1 | 3.4 | 1.6–6.4 | 1.9 | 0.6–4.4 | 6.9 | 4.1–10.7 |
| Navigators | 35.7 | 24.6–48.1 | 2.6 | 0.3–9.9 | 17.1 | 9.2–28.0 | 7.1 | 2.4–15.9 | 2.9 | 0.3–9.9 | 0.0 | 0.0–5.1 | 2.9 | 0.3–9.9 |
| Paratroopers | 52.2 | 36.9–67.1 | 8.5 | 2.4–20.4 | 23.4 | 12.3–38.0 | 4.2 | 0.5–14.5 | 4.3 | 0.5–14.8 | 2.2 | 0.1–11.5 | 4.3 | 0.5–14.8 |
| Others | 38.5 | 20.2–59.4 | 3.8 | 0.1–19.6 | 38.5 | 20.2–59.4 | 3.8 | 0.1–19.6 | 7.7 | 0.9–25.1 | 0.0 | 0.0–13.2 | 11.5 | 2.4–30.2 |
| *P*-value | NS | | *** | | *** | | ** | | * | | * | | * | |
| Aviation type | | | | | | | | | | | | | | |
| Civilian | 56.8 | 54.0–59.5 | 33.9 | 31.3–36.5 | 18.1 | 16.0–20.2 | 16.2 | 14.2–18.3 | 5.9 | 4.7–7.3 | 3.5 | 2.6–4.6 | 11.6 | 9.9–13.5 |
| Military | 33.7 | 31.3–36.2 | 6.5 | 5.3–7.8 | 16.9 | 15.0–18.9 | 9.1 | 7.6–10.6 | 3.8 | 2.9–4.9 | 2.7 | 1.9–3.6 | 7.2 | 5.9–8.6 |
| *P*-value | *** | | *** | | NS | | *** | | * | | NS | | *** | |
| License profile | | | | | | | | | | | | | | |
| Applicants | 19.9 | 16.3–23.9 | 0.4 | 0.1–1.6 | 18.6 | 15.1–22.5 | 5.8 | 3.8–8.4 | 2.5 | 1.2–4.4 | 2.0 | 0.9–3.8 | 2.7 | 1.4–4.6 |
| Trained aircrew | 49.3 | 47.3–51.4 | 23.1 | 21.4–24.8 | 17.2 | 15.7–18.8 | 13.7 | 12.3–15.1 | 5.2 | 4.4–6.2 | 3.2 | 2.6–4.0 | 10.5 | 9.3–11.8 |
| *P*-value | *** | | *** | | NS | | *** | | * | | NS | | *** | |
| Number of CVRF (mean) | 2.06 | 1.99–2.12 | 2.69 | 2.59–2.79 | 1.95 | 1.85–2.06 | 2.96 | 2.81–3.10 | 3.51 | 3.26–3.77 | 3.72 | 3.33–4.10 | 3.39 | 3.22–3.55 |
| Global 10-yr CV risk (mean) | | | | | | | | | | | | | | |
| SCORE | 1.09 | 1.01–1.16 | 2.08 | 1.96–2.19 | 0.78 | 0.66–0.89 | 1.56 | 1.38–1.74 | 1.33 | 1.08–1.57 | 1.72 | 1.29–2.15 | 1.57 | 1.37–1.77 |
| Framingham | 8.69 | 8.29–9.08 | 13.31 | 12.67–13.94 | 7.50 | 6.80–8.20 | 11.70 | 10.77–12.62 | 11.52 | 9.98–13.06 | 13.07 | 10.69-15.46 | 13.16 | 11.98–14.35 |
| Risk levels from "moderate" to "very high" (%) | | | | | | | | | | | | | | |
| SCORE | 41.4 | 38.7–44.2 | 87.1 | 84.0–89.8 | 24.6 | 20.9–28.7 | 54.5 | 49.0–59.8 | 47.8 | 39.1–56.6 | 55.3 | 44.1-66.1 | 53.3 | 47.0–59.5 |
| Framingham | 34.4 | 31.8–37.1 | 62.1 | 57.8–66.2 | 27.3 | 23.4–31.5 | 53.0 | 47.6–58.4 | 48.5 | 39.8–57.3 | 51.8 | 40.7-62.7 | 55.2 | 48.9–61.4 |
| Summation | 61.8 | 59.0–64.5 | 89.5 | 86.6–92.0 | 53.0 | 48.4–57.4 | 16.4 | 12.7–20.8 | 89.6 | 83.1–94.2 | 88.2 | 79.4-94.2 | 92.7 | 88.8–95.5 |

HBP: high blood pressure; OSAS: obstructive sleep apnea syndrome; CI 95%: 95% confidence intervals; ATCO: air traffic control officer; CV: cardiovascular.
Values are expressed as percentages.
***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; NS: not significant.

**Table III.** Associated Factors with the Different CVRF (Multivariate Analyses by Logistic Regression Models).

| SOCIODEMOGRAPHIC/ | DYSLIPIDEMIA | | | HYPERTENSION | | | SMOKING | | | OBESITY | | | DIABETES OR PREDIABETES | | | OSAS AND/OR METABOLIC SD | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CVRF | OR | CI 95% | *P* | OR | CI 95% | *P* | OR | CI 95% | *P* | OR | CI 95% | *P* | OR | CI 95% | *P* | OR | CI 95% | *P* |
| Age groups (yr) | | | | | | | | | | | | | | | | | | |
| 18–34 | 0.30 | 0.25–0.56 | *** | 0.75 | 0.50–1.14 | NS | 1.13 | 0.86–1.49 | NS | 0.67 | 0.35–12.9 | NS | 0.93 | 0.40–2.23 | NS | 0.28 | 0.16–0.47 | *** |
| 35–44 (reference) | 1 | | | 1 | | | 1 | | | 1 | | | 1 | | NS | 1 | | |
| 45–54 | 2.46 | 1.94–3.13 | *** | 1.99 | 1.39–2.89 | *** | 0.78 | 0.57–1.05 | NS | 1.28 | 0.75–2.23 | * | 2.01 | 0.97–4.42 | NS | 1.09 | 0.73–1.64 | NS |
| 55–64 | 7.19 | 4.69–11.34 | *** | 2.55 | 1.64–4.00 | *** | 0.69 | 0.44–1.07 | NS | 1.48 | 0.75–2.92 | * | 4.33 | 1.87–10.53 | *** | 1.24 | 0.74–2.06 | NS |
| 65–74 | > 100 | | NS | 6.78 | 2.33–20.95 | *** | 0.22 | 0.01–1.13 | NS | 1.78 | 0.47–6.09 | NS | 6.02 | 1.30–24.68 | * | 4.49 | 1.42–14.16 | ** |
| Gender | | | | | | | | | | | | | | | | | | |
| Male (reference) | 1 | | | 1 | | | 1 | | | 1 | | | 1 | | | 1 | | |
| Female | 0.46 | 0.32–0.65 | *** | 0.34 | 0.17–0.63 | ** | 0.75 | 0.52–1.07 | NS | 0.84 | 0.35–1.86 | NS | 0.29 | 0.06–0.95 | NS | 0.38 | 0.17–0.79 | * |
| Aircrew roles | | | | | | | | | | | | | | | | | | |
| Pilots (reference) | 1 | | | 1 | | | 1 | | | 1 | | | 1 | | | 1.00 | | |
| Rear crew | 1.44 | 1.09–1.89 | ** | 1.45 | 0.98–2.12 | NS | 2.32 | 1.73–3.11 | *** | 0.84 | 0.42–1.58 | NS | 1.83 | 0.91–3.60 | NS | 1.38 | 0.86–2.16 | NS |
| ATCO | 1.56 | 1.12–2.18 | ** | 1.91 | 1.22–2.96 | ** | 2.81 | 1.98–3.96 | *** | 2.08 | 1.11–3.83 | * | 2.34 | 1.09–4.91 | * | 1.53 | 0.90–2.56 | NS |
| Cabin crew | 0.92 | 0.62–1.39 | NS | 1.09 | 0.57–2.02 | NS | 3.39 | 2.24–5.13 | *** | 0.95 | 0.36–2.28 | NS | 2.01 | 0.58–5.83 | NS | 1.41 | 0.67–2.84 | NS |
| Navigators | 1.41 | 0.79–2.44 | NS | 1.18 | 0.39–2.86 | NS | 1.69 | 0.84–3.15 | NS | 1.17 | 0.18–4.34 | NS | < 0.01 | | NS | 0.56 | 0.09–1.95 | NS |
| Paratroopers | 1.31 | 0.68–2.54 | NS | 0.33 | 0.05–1.13 | NS | 2.09 | 0.99–4.09 | * | 1.41 | 0.22–4.97 | NS | 1.47 | 0.08–7.51 | NS | 0.45 | 0.07–1.62 | NS |
| Others | 1.56 | 0.62–3.74 | NS | 0.44 | 0.02–2.31 | NS | 4.85 | 2.07–10.9 | *** | 2.55 | 0.36–10.8 | NS | < 0.01 | | NS | 2.38 | 0.50–8.18 | NS |
| Aviation type | | | | | | | | | | | | | | | | | | |
| Civilian (reference) | 1 | | | 1 | | | 1 | | | 1 | | | 1 | | | 1 | | |
| Military | 0.76 | 0.61–0.96 | * | 0.76 | 0.54–1.05 | NS | 0.70 | 0.53–0.92 | * | 0.93 | 0.55–1.56 | NS | 1.27 | 0.66–2.43 | NS | 1.06 | 0.71–1.58 | NS |
| CVRF | | | | | | | | | | | | | | | | | | |
| Dyslipidemia | | - | | 1.74 | 1.29–2.37 | *** | 1.18 | 0.93–1.49 | NS | 1.65 | 1.02–2.72 | * | 0.89 | 0.50–1.63 | NS | 2.08 | 1.44–3.04 | *** |
| Hypertension | 1.72 | 1.27–2.33 | *** | | - | | 0.85 | 0.60–1.18 | NS | 2.32 | 1.51–3.55 | *** | 1.45 | 0.84–2.46 | NS | 3.14 | 2.25–4.37 | *** |
| Smoking | 1.18 | 0.94–1.50 | NS | 0.85 | 0.6–1.19 | NS | | - | | 1.26 | 0.78–2.00 | NS | 1.31 | 0.73–2.27 | NS | 1.43 | 0.98–2.07 | NS |
| Obesity | 1.53 | 0.95–2.51 | NS | 2.37 | 1.54–3.60 | *** | 1.23 | 0.77–1.94 | NS | | - | | 1.58 | 0.83–2.92 | NS | 6.11 | 3.95–9.44 | *** |
| OSAS and/or metabolic SD | 2.02 | 1.40–2.94 | *** | 3.12 | 2.24–4.34 | *** | 1.45 | 1.00–2.08 | * | 6.02 | 3.91–9.27 | *** | 7.57 | 4.43–13.05 | *** | | - | |
| Diabetes or prediabetes | 0.89 | 0.48–1.64 | NS | 1.3 | 0.74–2.24 | NS | 1.27 | 0.72–2.19 | NS | 1.36 | 0.69–2.57 | NS | | | | 8.1 | 4.65–14.15 | *** |

CVRF: cardiovascular risk factors; OR: odds ratio; CI: confidence interval; SD: syndrome; ATCO: air traffic control officer; OSAS: obstructive sleep apnea syndrome.
****P* < 0.001; ***P* < 0.01; **P* < 0.05; NS: not significant.

(0.20–0.28) in women]. On the other hand, the distribution of risk levels according to gender seemed to be favorable to this population.[18] In parallel, the ELISABET study reported a Framingham score of 14–15% in men and 6% in women, compared with 9.8% and 3.7%, respectively, in aircrew. From 2007–2012, a study carried out in the "Hauts-de-Seine" department on 6504 adults in primary prevention without treatment made it possible to estimate this same risk at 11.7% in men and 5.9% in women.[13] For identical age groups, our results were 9.8% and 5.7%, respectively.

Internationally, a favorable trend for aircrew was also revealed in the light of comparisons of the Framingham risk with the general populations of southern Europe[1] and North America.[7] Our results, when limited to civilian pilots only, found an overall Framingham score identical to that of British airline pilots (8.29% vs. 8.41%).[11] The aircrew population, who is presumed to be in good health through medical selection and regular monitoring, would therefore be less at risk from a cardiovascular perspective than the general population. The role of social determinants in cardiovascular risk has thus been demonstrated at the level of European populations.[21,22] However, after multivariate analyses based on logistic regression models, no significant association between cardiovascular risk levels and aviation professional duties could be retained (**Table IV**).

One of this study objectives was to find a possible profile of interest in applicants with at least one CVRF in order to better characterize the factors of CV risk emergence. In this subgroup, the results highlighted systolic blood pressure and LDL-c as the only clinical and biological parameters significantly associated with the CV risk, in parallel with a high prevalence of dyslipidemia and smoking as concrete CVRF in this early risk identification. On the basis of these criteria, the Framingham score allowed documentation of a significantly higher global CV risk in the presence of at least one CVRF among applicants. Finally, at this number of applicants, the highlighting of an absolute risk greater than that of trained aircrew (after adjustment for age and gender) did not find an obvious explanation. The hypothesis of an influential contribution of the professional category "Others" within applicants could be put forward, the latter bringing together military people at an already advanced stage of their career, with more than a third of them being smokers (38.5%), dyslipidemic (38.5%), or affected by prediabetes (30.8%). Another hypothesis would be to consider the benefit of the selection criteria and close medical supervision on the CV risk control in favor of people already enrolled in professional aircrew categories.

In the current state of our knowledge, this study relates to one of the largest cohorts devoted to CVRF and the global 10-yr CV risk assessment in aircrew, without equivalent data in

**Table IV.** Associated Factors Associated with the Primary Outcomes (Multivariate Analyses).

| | GLOBAL CV RISK LEVELS FROM "MODERATE" TO "VERY HIGH" | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SCORE | | | FRAMINGHAM | | | SUMMATION | | | ≥ 1 CVRF IN APPLICANTS | | |
| SOCIODEMOGRAPHIC | OR | CI 95% | *P* | OR | CI 95% | *P* | OR | CI 95% | *P* | OR | CI 95% | *P* |
| Age | 2.53 | 2.24–2.91 | *** | 1.65 | 1.55–1.77 | *** | 1.17 | 1.15–1.19 | *** | 0.96 | 0.86–1.06 | NS |
| Gender | | | | | | | | | | | | |
| Male (reference) | 1 | | | 1 | | | 1 | | | 1 | | |
| Female | <0.01 | | *** | 0.06 | 0.01–0.25 | *** | 1.03 | 0.53–1.98 | NS | 0.38 | 0.06–1.78 | NS |
| Aircrew roles | | | | | | | | | | | | |
| Pilots (reference) | 1 | | | 1 | | | 1 | | | 1 | | |
| Rear crew | 0.74 | 0.30–1.77 | NS | 0.95 | 0.45–1.97 | NS | 1.23 | 0.80–1.90 | NS | 0.46 | 0.15–1.37 | NS |
| ATCO | 0.66 | 0.27–1.63 | NS | 1.00 | 0.45–2.17 | NS | 0.87 | 0.53–1.43 | NS | 2.59 | 0.66–1.07 | NS |
| Cabin crew | 0.34 | 0.08–1.31 | NS | 0.89 | 0.28–2.79 | NS | 0.72 | 0.38–1.36 | NS | 2.63 | 0.15–3.18 | NS |
| Navigators | 0.89 | 0.10–6.28 | NS | 1.06 | 0.12–6.45 | NS | 0.79 | 0.28–2.07 | NS | -§ | | |
| Paratroopers | 0.71 | 0.05–5.34 | NS | 0.64 | 0.10–3.26 | NS | 0.5 | 0.18–1.30 | NS | 1.72 | 0.09–28.58 | NS |
| Others | 0.43 | <0.01–112.86 | NS | 1.20 | 0.03–21.29 | NS | 0.92 | 0.26–2.98 | NS | 1.97 | 0.20–16.27 | NS |
| Aviation type | | | | | | | | | | | | |
| Civilian (reference) | 1 | | | 1 | | | 1 | | | 1 | | |
| Military | 1.38 | 0.73–2.65 | NS | 1.32 | 0.75–2.32 | NS | 0.74 | 0.52–1.06 | NS | 1.01 | 0.30–3.55 | NS |
| Biometrics | | | | | | | | | | | | |
| SBP | 1.15 | 1.11–1.19 | *** | 1.12 | 1.09–1.16 | *** | 1.07 | 1.05–1.09 | *** | 1.10 | 1.03–1.18 | ** |
| DBP | 1.02 | 0.98–1.06 | NS | 1.01 | 0.98–1.04 | NS | 1.03 | 1.01–1.05 | ** | 1.04 | 0.97–1.10 | NS |
| Waist circumference | 1.03 | 0.97–1.08 | NS | 1.02 | 0.98–1.06 | NS | 1.03 | 1.00–1.06 | * | 0.96 | 0.87–1.06 | NS |
| BMI | 0.94 | 0.81–1.09 | NS | 1.02 | 0.90–1.16 | NS | 1.13 | 1.04–1.23 | ** | 1.26 | 0.98–1.63 | NS |
| Biology | | | | | | | | | | | | |
| FBG | 1.77 | 0.15–1.75 | NS | 8.21 | 1.00–87.06 | NS | 135.85 | 23.83–802.52 | *** | >100 | 1.02 – >100 | NS |
| Triglycerides | 1.70 | 1.04–2.70 | * | 1.98 | 1.37–2.94 | *** | 1.45 | 1.10–1.92 | ** | 1.39 | 0.50–4.00 | NS |
| HDL-c | 11.80 | 1.08–135.49 | * | <0.01 | | *** | 0.52 | 0.15–1.78 | | 28.88 | 0.46 – >100 | NS |
| LDL-c | 22.11 | 8.87–58.80 | *** | 42.97 | 19.92–97.27 | *** | 13.55 | 8.34–22.32 | *** | >100 | | *** |
| Smoking | 134.28 | 53.79–366.14 | *** | 127.06 | 59.52–290.20 | *** | 26.71 | 17.83–40.78 | *** | >100 | <0.01 – >100 | NS |

§Insufficient enrollment (the "Navigator" duty is only defined for trained aircrew, the corresponding license for applicants is "Pilot").

****P* < 0.001; ***P* < 0.01; **P* < 0.05; NS: not significant.

CV: cardiovascular; CVRF: cardiovascular risk factors; OR: odds ratio; CI: confidence interval; ATCO: air traffic control officer; SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index; FBG: fasting blood glucose; HDL-c: high density lipoprotein cholesterol; LDL-c: low density lipoprotein cholesterol.

France except for a few declarative collections by questionnaires. Our activity, within one of the only two French military AeMC, allowed the recruitment of the largest possible panel of aircrew categories in France, including both military and civilian, but also private components issued from industrial and commercial sectors.

The comparisons between aircrew categories constituted a strong point of this survey, with reference to the previously cited publications. Several pitfalls are, however, to be highlighted, including its monocentric nature, which limited its representativeness. Some analyses could lack power due to limited numbers for the oldest age groups or for the female population, very weakly represented among the majority of the professional roles studied. Anthropometric data were collected on the day of the licensing medical visit by trained health professionals. On the other hand, biological data underlines a methodological limitation. In fact, with the exception of applicants for whom blood exams were processed by the biology laboratory at Sainte-Anne Military Hospital, the majority of biochemical analyses could not be performed on the day of the visit. The data, therefore, came from city laboratories, with mean delay of 1.39 yr (1.32–1.46) at the date of the test. In addition, the cases of diabetes and OSAS, very poorly represented in our study, were selected on the basis of a previously documented diagnosis in the medical file: this was a potential source of underestimation. The treatment of missing data based on multiple imputations by chained equations allowed us, despite sometimes high proportions, to exploit all the available data without affecting the statistical analyses power.

Some CVRF, although unanimously recognized by the scientific community, have not been taken into account, such as heredity, sedentary lifestyle linked to a lack of physical activities, an unsuitable diet, or even excessive alcohol consumption.[24] This methodological choice made it possible to limit an information bias linked to strictly declarative data, in particular in this medical context concluded by a fitness to fly decision and for which a certain degree of relative omission should be considered. Note that despite its strictly declarative nature, smoking habits were nevertheless included. This systematic assessment in our daily practice has indeed encouraged us to utilize it so as not to overlook a major factor included in predictive risk models. Therefore, the main useful parameters for estimating the global 10-yr CVD risk were collected.

The comparisons with the general population were based on estimated prevalences by direct standardization and weighting results by the gender and age group distributions of reference populations. These comparisons are both an advantage and one of the main limitations of our study, illustrating an important "Healthy Worker Effect" as selection bias.[19] Indeed, morbidity and mortality rates are commonly lower among aviation and military workers than in the general population, on the intuitive basis that their health conditions must be compatible with standards of recruitment and retention in professional roles. The aircrew population is particularly sensitive to this bias, imposed by the rigor of selection and medical supervision standards. Comparisons with the general population are a clear illustration of this, but, in the particular case of primary CVD prevention, they nevertheless demonstrate the performance of aviation medicine in the control of determinants likely to compromise professional suitability.

In current practice, our results suggest paying particular attention to cardiovascular prevention in people at "moderate" risk; the occurrence of CVD for such a level of risk could prompt strategic thinking around preventive medicine. A large international cohort revealed that the majority of coronary artery disease, especially in Western Europe, occurred in the presence of a single "conventional" risk factor (smoking, dyslipidemia, diabetes, or hypertension).[14] Age appeared to be the most important sociodemographic factor associated with the risk models tested (Table IV) and our results showed, despite a very low number of people in secondary prevention, consistent results through a similar age profile between "moderate" and "very high" risk levels. Prevention therefore deserves to be promoted for people with a "moderate" global risk level. It could be organized around screening and reinforced control of CVRF, in particular dyslipidemia and arterial hypertension, in accordance with the issues already identified in the general population[5,20] and those predicted by recent recommendations.[15] Smoking should be the subject of a priority prevention axis among applicants.

Our results also underline the need to carry out future comparisons through larger scale studies between aircrew categories to better document the possible translation of various operational and workplace constraints. Despite the lack of significant association with the tested predictive models, the profile of air traffic controllers, highly involved in aviation safety and exposed to sedentary and shift work, nevertheless seems to call for particular vigilance. Finally, models for assessing a global CVD risk can benefit from recalibrations in order to guarantee a relevant use for the benefit of populations with variable morbidity and mortality and maintain their performance by integrating the epidemiological trends of the CVRF.[23] The value of a prospective study designed to evaluate these models with a view to a specific adjustment to certain professional categories involved in safety functions, in particular aeronautics, could be discussed. As an illustration, a New Zealand case-control study conducted with airline pilots did not demonstrate the expected 5-yr predictive performance of the Framingham model.[27]

This original study was conducted for the benefit of a professional population whose medical approach is inseparable from the essential concepts of risk control and aviation safety. Beyond the translation of favorable cardiovascular health, crediting the medical selection standards and close supervision, areas for improvement have been identified, inviting the development of prevention strategies around the "moderate" risk level, but also some conventional risk factors, which already are a source of issues in the general population, as reported above. The challenges and limits represented by global risk modeling will also have to change in response to individualized decisions based on additional risk factors currently not taken into account, such as metabolic syndrome, prediabetes, or OSAS, whose predictive involvement will deserve to be specified in the future.

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## REFERENCES

1. Artigao-Rodenas LM, Carbayo-Herencia JA, Divisón-Garrote JA, Gil-Guillén VF, Massó-Orozco J, et al. Grupo de Enfermedades Vasculares de Albacete (GEVA). Framingham risk score for prediction of cardiovascular diseases: a population-based study from southern Europe. PLoS One. 2013; 8(9):e73529.
2. Clément G. Prévalence des principaux facteurs de risque cardiovasculaire dans les agglomérations de Lille et Dunkerque entre 2011 et 2013, et évolution à Lille entre 1985 et 2013. Thèse pour le diplôme d'état de docteur en médecine. Université Lille 2 Droit et Santé, Faculté de médecine Henri Warembourg, 2015. [Publication in French]. [Accessed March 14, 2024]. Available from https://pepite-depot.univ-lille.fr/LIBRE/Th_Medecine/2015/2015LIL2M280.pdf.
3. Conroy RM, Pyörälä K, Fitzgerald AP, Sans S, Menotti A, et al.; SCORE project group. Estimation of ten-year risk of fatal cardiovascular disease in Europe: the SCORE project. Eur Heart J. 2003; 24(11):987–1003.
4. Cupples LA, D'Agostino RB. Section 34: some risk factors related to the annual incidence of cardiovascular disease and death in pooled repeated biennial measurements. In: Kannel WB, Wolf PA, Garrison RJ, eds. Framingham Heart Study: 30 year follow-up. Bethesda (MD): U.S. Department of Health and Human Services; 1987.
5. De Peretti C, Pérel C, Chin F, Tuppin P, Iliou MC, et al. Cholestérol LDL moyen et prévalence de l'hypercholestérolémie LDL chez les adultes de 18 à 74ans, Étude nationale nutrition santé (ENNS) 2006-2007, France. Bull Epidémiol Hebd. 2013; 31:378–385. [Article in French]. [Accessed March 12, 2024]. Available from http://beh.santepubliquefrance.fr/beh/2013/31/2013_31_1.html.
6. Evans S, Radcliffe SA. The annual incapacitation rate of commercial pilots. Aviat Space Environ Med. 2012; 83(1):42–49.
7. Ford ES. Trends in predicted 10-year risk of coronary heart disease and cardiovascular disease among U.S. adults from 1999 to 2010. J Am Coll Cardiol. 2013; 61(22):2249–2252. [Accessed March 12, 2024]. Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4571185/pdf/nihms717844.pdf.
8. Gaines J, Vgontzas AN, Fernandez-Mendoza J, Bixler EO. Obstructive sleep apnea and the metabolic syndrome: the road to clinically-meaningful phenotyping, improved prognosis, and personalized treatment. Sleep Med Rev. 2018; 42:211–219. [Accessed March 12, 2024]. Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6221996/pdf/nihms-1505688.pdf.
9. GBD 2017 DALYs and HALE Collaborators. Global, regional, and national disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2018; 392(10159):1859–1922.
10. Gray G, Bron D, Davenport ED, d'Arcy J, Guettler N, et al. Assessing aeromedical risk: a three-dimensional risk matrix approach. Heart. 2019; 105(Suppl 1):s9–s16.
11. Houston S, Mitchell S, Evans S. Application of a cardiovascular disease risk prediction model among commercial pilots. Aviat Space Environ Med. 2010; 81(8):768–773.
12. Joseph P, Leong D, McKee M, Anand SS, Schwalm JD, et al. Reducing the global burden of cardiovascular disease, part 1: the epidemiology and risk factors. Circ Res. 2017; 121(6):677–694.
13. Karam C, Beauchet A, Czernichow S, de Roquefeuil F, Bourez A, et al. Trends in cardiovascular disease risk factor prevalence and estimated 10-year cardiovascular risk scores in a large untreated French urban population: The CARVAR 92 Study. PLoS One. 2015; 10(4):e0124817.
14. Khot UN, Khot MB, Bajzer CT, Sapp SK, Ohman EM, et al. Prevalence of conventional risk factors in patients with coronary heart disease. JAMA. 2003; 290(7):898–904.
15. Mach F, Baigent C, Catapano AL, Koskinas KC, Casula M, et al.; ESC Scientific Document Group. 2019 ESC/EAS Guidelines for the management of dyslipidaemias: lipid modification to reduce cardiovascular risk. Eur Heart J. 2020; 41(1):111–188.
16. Majed B, Tafflet M, Kee F, Haas B, Ferrieres J, et al.; PRIME study group. External validation of the 2008 Framingham cardiovascular risk equation for CHD and stroke events in a European population of middle-aged men. The PRIME study. Prev Med. 2013; 57(1):49–54.
17. Nicol ED, Rienks R, Gray G, Guettler NJ, Manen O, et al. An introduction to aviation cardiology. Heart. 2019; 105(Suppl. 1):s3–s8.
18. Parisot J. Risque cardio-vasculaire et genre: tendances de risques chez les femmes et les hommes de la cohorte CONSTANCES. Thèse pour le diplôme d'état de docteur en médecine. Université de Versailles Saint-Quentin-en-Yvelines, UFR des Sciences de la Santé Simone Veil. [Publication in French]. [Accessed March 12, 2024]. Available from http://www.sfmg.org/data/generateur/generateur_fiche/1413/fichier_these_medecine_juliette_parisot_version_pour_impression4a992.pdf.
19. Pearce N, Checkoway H, Kriebel D. Bias in occupational epidemiology studies. Occup Environ Med. 2007; 64(8):562–568.
20. Perrine AL, Lecoffre C, Blacher J, Olié V. L'hypertension artérielle en France: prévalence, traitement et contrôle en 2015 et évolutions depuis 2006. Bull Epidémiol Hebd. 2018; (10):170–179. [Article in French]. [Accessed March 12, 2024]. Available from http://invs.santepubliquefrance.fr/beh/2018/10/2018_10_1.html.
21. Piepoli MF, Hoes AW, Agewall S, Albus C, Brotons C, et al.; ESC Scientific Document Group. 2016 European Guidelines on cardiovascular disease prevention in clinical practice: The Sixth Joint Task Force of the European Society of Cardiology and Other Societies on Cardiovascular Disease Prevention in Clinical Practice (constituted by representatives of 10 societies and by invited experts). Developed with the special contribution of the European Association for Cardiovascular Prevention & Rehabilitation (EACPR). Eur Heart J. 2016; 37(29):2315–2381.
22. Ramsay SE, Morris RW, Whincup PH, Papacosta AO, Thomas MC, Wannamethee SG. Prediction of coronary heart disease risk by Framingham and SCORE risk assessments varies by socioeconomic position: results from a study in British men. Eur J Cardiovasc Prev Rehabil. 2011; 18(2):186–193.
23. Rospleszcz S, Thorand B, de Las Heras Gala T, Meisinger C, Holle R, et al. Temporal trends in cardiovascular risk factors and performance of the Framingham Risk Score and the Pooled Cohort Equations. J Epidemiol Community Health. 2019; 73(1):19–25.
24. Studziński K, Tomasik T, Krzysztoń J, Jóźwiak J, Windak A. Effect of using cardiovascular risk scoring in routine risk assessment in primary prevention of cardiovascular disease: an overview of systematic reviews. BMC Cardiovasc Disord. 2019; 19(1):11.
25. Townsend N, Wilson L, Bhatnagar P, Wickramasinghe K, Rayner M, Nichols M. Cardiovascular disease in Europe: epidemiological update 2016. Eur Heart J. 2016; 37(42):3232–3245.
26. Tunstall-Pedoe H. Cardiovascular risk and risk factors in the context of aircrew certification. Eur Heart J. 1992; 13(Suppl. H):16–20.
27. Wirawan IM, Larsen PD, Aldington S, Griffiths RF, Ellis CJ. Cardiovascular risk score and cardiovascular events among airline pilots: a case-control study. Aviat Space Environ Med. 2012; 83(5):465–471.
28. Little RJ, Rubin DB. Statistical Analysis with Missing Data. 3rd ed. New York: Wiley; 2019.