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Aerospace Medicine and Human Performance

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Aerospace Medicine and Human Performance

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This journal, representing the members of the Aerospace Medical Association, is published for those interested in aerospace medicine and human performance. It is devoted to serving and supporting all who explore, travel, work, or live in hazardous environments ranging from beneath the sea to the outermost reaches of space.

AEROSPACE MEDICAL ASSOCIATION is an organization devoted to charitable, educational, and scientific purposes. The Association was founded when the rapid expansion of aviation made evident the need for physicians with specialized knowledge of the flight environment. Since then, physicians have been joined in this Association by professionals from many fields and from many countries, all linked by a common interest in the health and safety of those who venture into challenging environments.

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MAY 2024 VOLUME 95 NUMBER 5

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CHICAGO, IL

ADVANCE REGISTRATION FORM
AEROSPACE MEDICAL ASSOCIATION
94th ANNUAL SCIENTIFIC MEETING

MAY 5–10, 2024

- **Early Bird Registration runs January 1–31. (Mail registrations must be postmarked with a January date.)**
- **Advance Registration runs February 1 – May 4.**
- **NO CANCELLATIONS OR REFUNDS AFTER APRIL 30. *A $50 ADMINISTRATIVE FEE IS APPLIED TO ALL CANCELLATIONS.***

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☐ NON-MEMBER PRESENTER	$625†*	$750*	$850*	
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(See reverse for workshops & events)

NOTE: WORKSHOPS ARE LIMITED *** REGISTER EARLY

WORKSHOP DATE/NAME	FEE	Total Fee
☐ Sun., May 5, 8:00 am – 5:00 am Workshop: "Aerospace Epidemiology – The Science of the Denominator" (MAX 50)	$200	
☐ Sun., May 5, 8:00 am – 5:00 pm Workshop: "Clear Skies Ahead: Achieving and Sustaining Mental Wellness in the Aerospace System of Tomorrow" (MAX 125)	$200	
☐ Sun., May 5, 9:00 am – 4:00 pm Workshop: "Understanding and Managing Fatigue in Aviation" (MAX 75)	$150	
☐ Fri., May 10, 8:00 am – 5:00 pm Workshop: "Space Mission Analogs: Medical Care in Remote Maritime Operations" (MAX 30)	$250	

EVENTS *(NOTE: Advance Purchase Only requires tickets to be purchased during Early Bird & Advance Registration – no tickets for these events will be sold onsite)*	# OF TICKETS	FEE PER TICKET	TOTAL FEE
☐ Sun., May 5, AsMA Welcome to Chicago **(NOTE: All Attending Event Must Have Tickets)**		$15	
☐ Mon., May 6, 6:00 am, Richard B. "Dick" Trumbo 5K Fun Run/Walk ***(Advance Purchase Only)***		$15	
☐ Mon., May 6, American Society of Aerospace Medicine Specialists (ASAMS) Breakfast & Business Meeting ***(Advance Purchase Only)*** **(ASAMS Members Only)**		$25	
☐ Mon., May 6, Aerospace Human Factors Association Luncheon ***(Advance Purchase Only)***		$50	
☐ Mon., May 6, Civil Aviation Medical Association Luncheon ***(Advance Purchase Only)***		$50	
☐ Mon., May 6, Society of U.S. Air Force Flight Surgeons Luncheon ***(Advance Purchase Only)***		$50	
☐ Mon., May 6, Society of U.S. Army Flight Surgeons Luncheon ***(Advance Purchase Only)***		$50	
☐ Mon., May 6, U.S. Navy Luncheon ***(Advance Purchase Only)***		$50	
☐ Mon., May 6, Fellows Dinner ***(Advance Purchase Only)*** **(MUST BE A FELLOW OR GUEST OF AsMA FELLOW)**		$90	
☐ Tues., May 7, Associate Fellows Breakfast ***(Advance Purchase Only)***		$50	
☐ Tues., May 7, AsMA Annual Business Meeting ***(Advance Purchase Only)*** **(Free Attendance; Ticket required for meal)**		$50	
☐ Tues., May 7, Alliance of Air National Guard Flight Surgeons Luncheon ***(Advance Purchase Only)***		$50	
☐ Tues., May 7, Reception to Honor International Attendees		$25	
☐ Wed., May 8, Canadian Society of Aerospace Medicine Breakfast ***(Advance Purchase Only)***		$50	
☐ Wed., May 8, Aerospace Nursing & Allied Health Professionals Society Luncheon ***(Advance Purchase Only)***		$50	
☐ Wed., May 8, Aerospace Physiology Society Luncheon ***(Advance Purchase Only)***		$50	
☐ Wed., May 8, Iberoamerican Association of Aerospace Medicine Luncheon ***(Advance Purchase Only)***		$50	
☐ Wed., May 8, Society of NASA Flight Surgeons Luncheon ***(Advance Purchase Only)***		$50	
☐ Thur., May 9, Space Medicine Association Luncheon		$50	
☐ Thur., May 9, AsMA Honors Night Banquet **(Black Tie Optional)**		$90	
		SUBTOTAL OF EVENTS	
TOTAL AMOUNT DUE (Registration Fee Subtotal + Workshop + Subtotal of Events)			

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May 5 - 9, 2024
Hyatt Regency, Chicago
Chicago, Illinois

The WING of AsMA
AsMA 94th Annual Scientific Meeting

REGISTRATION FORM

Please read the entire form before filling out or registering online. Fill out a separate form for each registrant.
Advance Registration closes *April 19, 2024*. No refunds *after April 26, 2024.*
Enter the TOTAL NUMBER of tickets and TOTAL DOLLAR AMOUNT on the line after each activity.
Send your advance registration directly to THE WING or register online.
DO NOT include with your spouse's/sponsor's AsMA registration.

***PLEASE NOTE: All prices are in U.S. dollars. Only U.S. funds will be accepted for Registration.**

NOTE: Registration is mandatory for participation in Wing activities.

Wing Dues (May 2024 – May 2025) **$35.00** $________________

☐ New Member 2024 ☐ Renewal ☐ 2024 Dues Previously Paid

Compulsory Registration Fee (advanced reg. $40.00, on-site: $50.00) $________________

- **Monday, May 6, Welcome Reception, 1:00 PM – 4:30 PM**
  The WING Welcome Reception for Registrants only **INCLUDED** No.____ $ 0.00
- **Tuesday, May 7, 10:00 AM – 12:00 PM** **$45.00** No.____ $__________
  (Meet in Lobby @ 9:30 AM)
  Architectural Boat Tour
- **Wednesday, May 8, 11:00 AM – 1:00 PM** **$50.00** No.____ $__________
  (Meet in Lobby @ 10:30 AM)
  Annual Wing Luncheon & Business Meeting McCormick & Schmick's
- **Thursday, May 9, All Day!** **$0.00**
  Chicago at your Leisure. You pick where and with whom and go!

TOTAL **$** 0.00

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Mail this form and your check (payable to Wing of AsMA in US DOLLARS) to:

Brenda Clinton, Treasurer
10603 Derby Mesa Court
Colorado Springs, CO 80924

The Wing of AsMA
Annual Meeting and Tour Information

<u>WELCOME RECEPTION</u>

Monday, May 6, 1:30 – 4:30 PM

Connect with old friends and make some new ones in a relaxed environment at our annual Welcome Reception. *<u>Remember to bring a small gift reminiscent of your home city, state or country for the gift exchange and please include a short note letting the recipient know who/where the gift is from</u>.* ***New members and first-time attendees <u>don't</u> bring a gift as we are very happy to <u>welcome</u> you to THE WING!***

This year's Welcome Reception will be held in **THE Hyatt Regency CHICAGO HOTEL, *Plaza Ballroom A.***

<u>Architectural Boat Tour</u>

Tuesday, May 7, 10:00 AM – 12:00 PM — $45.00

Meet at 9:30 AM in the Lobby at The Hyatt Regency Chicago Hotel.

Tips included. After return to the hotel, lunch is on your own.

Discover the architectural gems of the Windy City from an ideal vantage point on a cruise down the Chicago River. Covering more than 130 years of architectural history, the tour is the perfect opportunity to see a huge area of the city. Enjoy unobstructed views of the city's top attractions and gain an in-depth understanding of local architecture.

<u>ANNUAL WING LUNCHEON & BUSINESS MEETING</u> — $50.00

<u>McCormick's & Schmick's</u>

Wednesday, May 8, 11:00 AM – 1:00 PM

1 East Wacker Drive, Chicago IL.

Meet in the lobby at 10:30 AM. We can walk together (a short walk from the hotel). We'll enjoy a lovely meal, discuss a little business and catch up with friends. Our Annual Wing Business meeting will be held in a delightful setting on East Wacker Street. Of course, it's just minutes away from the Chicago Theater, Oriental Theater, Millennium Park, various fun and unique Chicago shops. Please email to: **asmawing@gmail.com** if you request one of the dietary alternatives by **April 19, 2024.**

Thursday, May 9, All Day

Meet up with friends to head out for your favorite adventure. There is more to do in Chicago than pretty much anywhere else we've been! The weather should be great so bring some good walking shoes. Whether it's shopping on the Magnificent Mile, seeking adventure at the Navy Pier, relaxing at Millennial Park or touring the Chicago museums, it is all your choice. You cannot go wrong.

An Honor to Serve

Joseph Dervay, M.D., M.P.H., MMS, FACEP, FAsMA, FUHM

It has been an honor to serve as President of the Aerospace Medical Association (AsMA) this past year!

My final President's Page is required in March for a May publication, likely in print as we begin the Annual Scientific Meeting (ASM) in Chicago. As I pen this page, I wish to provide some observations, highlights, and share some "thank you's " and kudos.

I first became a member of AsMA in 1985 as a Student Naval Flight Surgeon and recall attending my first Annual meeting the next year in Nashville. I was a wide-eyed new attendee in awe of the scope of the program offered and the range of aerospace medicine professionals I met. The welcoming mentorship of former Executive Director Dr. Russell Rayman took me on a path to embrace AsMA and serve the organization in the years ahead in a multitude of roles and leadership positions. It has been a *labor of love* for me to have done so. I have been constantly impressed with the value and importance of *what you all do*, and will continue to do, in the arena of aerospace medicine, human performance, health, and safety.

As AsMA approaches the upcoming Annual Scientific Meeting in Chicago, we are very encouraged that the early rising trend of advanced registrations and hotel room bookings suggest a large number of attendees will be present to share professional knowledge and camaraderie. I greatly look forward to the outstanding guest speakers slated for the Armstrong Lecture, Reinartz Panel, and Bauer Lecture. A record number of abstracts for the Annual Scientific Meeting were submitted this past fall. The Scientific Program Committee (SPC), under the leadership of Dr. Eilis Boudreau, has worked arduously to help develop a solid scientific program. I thank the SPC for their many volunteer hours in doing so and for their upcoming efforts to address areas of improvement to guide abstract submitters and enhance the remote and in-person abstract review hybrid process.

The Home Office staff, led by our Executive Director, Jeff Sventek, are truly an outstanding group to work with. Their professionalism, devotion to the organization, and desire to serve our membership is truly heartfelt. A special thank you to Jeff, my "fellow colleague from Upstate New York", with whom I have had countless phone calls and virtual meetings throughout the year addressing issues for the organization. Your friendship and dedication to AsMA has always been appreciated and valued.

Thank you to the support and service of our Vice Presidents, Executive Committee members, Council members, Committee Chairs and members, and all our Constituents and Affiliates. Corporate sponsor membership is very much appreciated as these organizations support and value the mission of AsMA.

I thank the prior Past Presidents for their service to AsMA and their words of wisdom as I strove to shepherd and advance our organization. The *Aerospace Medicine and Human Performance* (AMHP) journal continues to remain an excellent publication and has smoothly transitioned into the digital print journal era. We have welcomed Dr. David Newman as the new AMHP Editor-in-Chief and are grateful for the years of outstanding work and guidance by Dr. Fred Bonato. Our organization's financial trajectory is doing very well as we exited the challenges of the COVID pandemic with solid planning and financial decisions having been made by our Executive Committee, Council, and Executive Director.

Thank you to Drs. Jeff Davis and Kris Belland as they have stepped up to lead the AsMA Ad Hoc Working Group on Aerospace Medicine Training. The Working Group's efforts are to thoroughly evaluate and recommend, in concert with input from the Education and Training Committee, the best and most appropriate pathways for future Aerospace Medicine practitioners as career opportunities unfold in the years ahead.

As I shared in a prior correspondence, AsMA and the Undersea & Hyperbaric Medical Society (UHMS) have been actively engaged in exploring and defining the most practical steps toward shared services and increased collaboration between the two organizations, which could greatly enhance our collective value to members and strengthen our scientific educational forums. During the spring 2024 Executive Committee (EXCOM) meeting in Texas, the UHMS Executive Director and President-Elect joined EXCOM in person for an entire day dedicated to continued evaluation of the many facets of such engagement. A Collaborations Committee, with four leadership members each from AsMA and UHMS has been established to continue the effort. A full briefing on progress made and issues identified will be presented at the May Council meeting in Chicago. Hopefully you are already aware that beginning with the 2025 Annual Scientific Meeting in Atlanta, AsMA and UHMS will hold a joint meeting for the foreseeable future. We are confident such an outstanding interaction will offer many benefits.

Observing the growth of our AMSRO student and resident membership levels the past few years, and their enthusiastic involvement in various AsMA committees and activities, has been very rewarding as we help young professionals join our cadre. Our international members are also truly vital to our growth and worldwide outreach, and their efforts to attend and participate at

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PRESIDENT'S PAGE, *continued*

our Annual Scientific Meetings are a testament to global cooperation. We will continue to encourage further growth and opportunities for internationals within our ranks. I appreciate the work of the International Academy of Aviation and Space Medicine, and groups such as the European Society of Aerospace Medicine and other professional societies to share knowledge through the International Congress of Aerospace Medicine, the International Congress of Aviation and Space Medicine, and other venues.

Soon our President-Elect, Dr. Bob Orford, will take the gavel as AsMA President. Bob is exceptionally professional and competent, and AsMA is in truly good hands as he takes the helm. It has been an absolute pleasure to serve with Bob.

During the Chicago meeting, I sincerely hope the Annual Scientific Meeting will provide a positive experience, allowing attendees to gain more knowledge, make new acquaintances, renew friendships, and reinforce the unique aspects of our international organization of like-minded colleagues. In 6 years we will be celebrating the 100th year Anniversary of AsMA. I look forward to what we will experience with aviation developments, technical and human factors advancements, impacts of Artificial Intelligence, deeper understanding of our universe, and expansion of human exploration both on planetary bodies and in the depths of the oceans.

This past January, my father Joe passed away at the age of 92. A Korean War era U.S. Air Force F-84/F-86 Crew Chief and mechanic, he shared with me his deep passion for aviation and technology as I grew up during the early years of the space program. As an IBM engineer, he was involved with placement of various electronic components into the instrumentation section of the Apollo rockets. He drove me all the way from Upstate New York to Florida in December of 1972 to witness the last, and only nighttime, Apollo launch, that of Apollo 17. I deeply wish he could have been at the Chicago Annual Scientific Meeting with my family to meet many of you and know he would be proud of all we collectively accomplish in making the world a better place and pushing the boundaries of exploration and science.

As I close my tenure as President, I feel truly blessed that AsMA has been "part of the fabric of my life" as a wonderful family of professional colleagues and friends from around the globe.

Honor quidem fuit servire.

All the best!

Keep 'em Flying…and Full Steam Ahead.

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.

Huiban N, Gehant M, Brocq F-X, Collange F, Mayet A, Monteil M. *Global cardiovascular risk and associated factors in 2792 French military and civilian aircrew*. Aerosp Med Hum Perform. 2024; 95(5):233–244.

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

From the Aeromedical Center, Sainte-Anne Military Hospital, Toulon; France; the French Military Medical Academy, Paris; France; and the Military Epidemiology and Public Health Center, Marseille; France.

This manuscript was received for review in December 2023. It was accepted for publication in January 2024.

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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 ≥ 1.10 g · L^{-1}. International Diabetes Federation criteria (IDF 2005) were used to define metabolic syndrome in the presence of a WC ≥ 94 cm (men) or 80 cm (women), associated with at least two factors among: blood pressure ≥ 130/85 mmHg; HDL-c < 0.4 g · L^{-1} (men) or < 0.5 g · L^{-1} (women); triglycerides ≥ 1.5 g · L^{-1}; or FBG ≥ 1.0 g · 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 · 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 · L^{-1} (1.52–1.81) for TC, 0.90 g · L^{-1} (0.78–1.03) for LDL-c, 0.52 g · L^{-1} (0.47–0.58) for HDL-c, and 1.08 g · 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 · 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

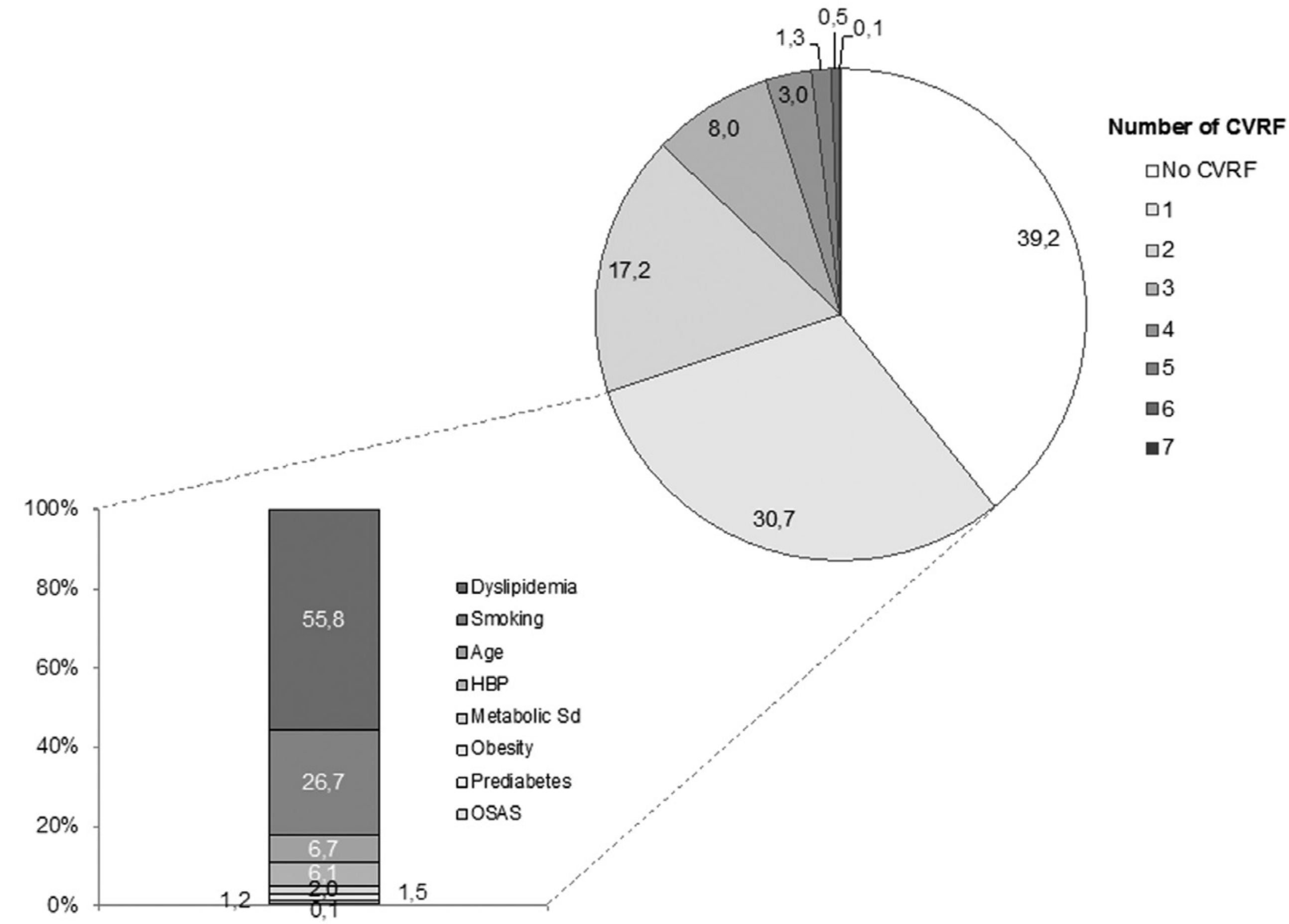

Fig. 2. Distribution of the number of CVRF and relative frequencies (in percentages) in a case of a single CVRF.

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

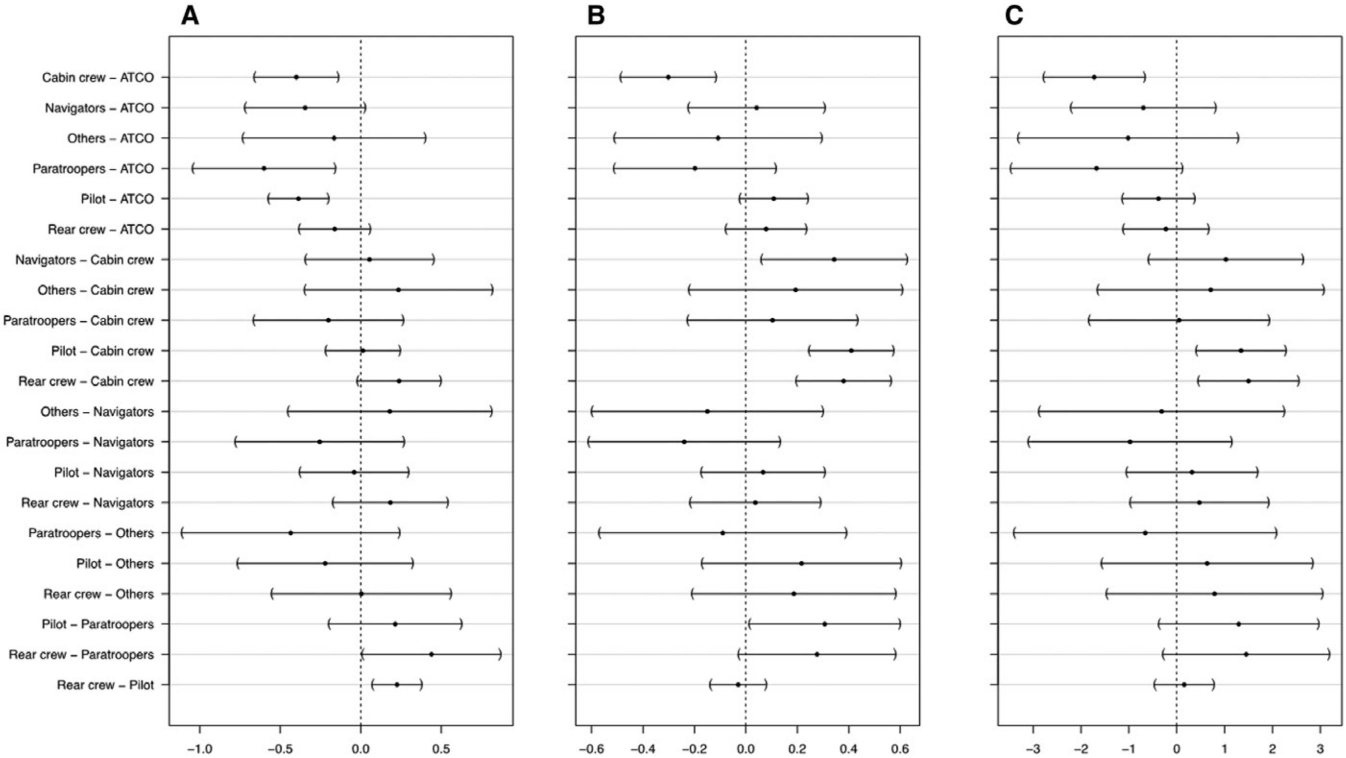

Fig. 3. Mean differences (with 95% confidence intervals) identified between the pairwised compared aircrew roles after adjustment for age and gender (linear regression), A) according to the number of CVRF; B) the SCORE risk; and C) the Framingham risk.

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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Modern Magnetic Resonance Imaging Modalities to Advance Neuroimaging in Astronauts

Lila Berger; Ford Burles; Tejdeep Jaswal; Rebecca Williams; Giuseppe Iaria

INTRODUCTION: The rapid development of the space industry requires a deeper understanding of spaceflight's impact on the brain. MRI research reports brain volume changes following spaceflight in astronauts, potentially affecting cognition. Recently, we have demonstrated that this evidence of volumetric changes, as measured by typical T1-weighted sequences (e.g., magnetization-prepared rapid gradient echo sequence; MPRAGE), is error-prone due to the microgravity-related redistribution of cerebrospinal fluid in the brain. More modern neuroimaging methods, particularly dual-echo MPRAGE (DEMPRAGE) and magnetization-prepared rapid gradient echo sequence utilizing two inversion pulses (MP2RAGE), have been suggested to be resilient to this error. Here, we tested if these imaging modalities offered consistent segmentation performance improvements in some commonly employed neuroimaging software packages.

METHODS: We conducted manual gray matter tissue segmentation in traditional T1w MRI images to utilize for comparison. Automated tissue segmentation was performed for traditional T1w imaging, as well as on DEMPRAGE and MP2RAGE images from the same subjects. Statistical analysis involved a comparison of total gray matter volumes for each modality, and the extent of tissue segmentation agreement was assessed using a test of similarity (Dice coefficient).

RESULTS: Neither DEMPRAGE nor MP2RAGE exhibited consistent segmentation performance across all toolboxes tested.

DISCUSSION: This research indicates that customized data collection and processing methods are necessary for reliable and valid structural MRI segmentation in astronauts, as current methods provide erroneous classification and hence inaccurate claims of neuroplastic brain changes in the astronaut population.

KEYWORDS: tissue segmentation, spaceflight, gray matter, dura, cerebrospinal fluid, volumetry.

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As the space industry progresses toward long-range space exploration,[1] it is becoming increasingly vital to understand the implications of space travel on the well-being of astronauts. This rapid growth can be attributed in part to the privatization of the industry, as companies have begun partnering with government agencies such as NASA to begin sending more civilians to space than ever before.[2] As of 2021, there have been over 600 astronauts that have been to space, and this number will only continue to increase as new plans develop to return to the moon.[3,4] Increases in the number of humans going to space presents both a necessity and an opportunity to study the effects of space travel on the brain.

Studies utilizing MRI have provided evidence that spaceflight causes structural changes to the brain.[5] These structural changes have the potential to impact the performance and safety of astronauts, therefore jeopardizing the success of space missions. For instance, Koppelmans and colleagues reported significant widespread decreases in gray matter (GM) volume postflight in the temporal and frontal lobes, precentral and postcentral gyrus, alongside various other changes in other brain regions.[6] These regions are necessary for various cognitive processes and for effective functioning, such as movement, planning, and decision-making.[7,8] Together, these studies suggest that exposure to microgravity (among other factors), as experienced during a spaceflight, has a significant effect on the

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volumes of selective regions in the brain, which may have an impact on the performance of astronauts during space missions.[9]

In addition to GM and white matter (WM) volume changes, spaceflight has also been shown to lead to changes in the distribution of cerebrospinal fluid (CSF) within the skull as an effect of exposure and adaptation to microgravity.[6,9,10] Common cognitive repercussions attributed to CSF redistribution in the brain include worsening memory function and the occurrence of the spaceflight-associated neuro-ocular syndrome (SANS),[10,11] which is reported in approximately one third of astronauts and is correlated with increases in ventricular volume.[12] SANS affects the vision of astronauts, posing significant risks to the performance and safety of crewmembers.[9]

Importantly, in addition to CSF redistribution, exposure to microgravity has been reported to have an impact on the location of the entire brain within the skull,[13] resulting in an upward shifting of the brain and local alterations in the distribution of CSF.[14,15] We have recently investigated this issue in order to examine the potential effects of preprocessing procedures on the data analyses investigating the volumetric brain changes related to spaceflight.[15] We demonstrated that relocation of the brain within the skull results in GM tissue segmentation errors, with the dura (part of the meninges surrounding the brain) being the most commonly misclassified tissue.[15] Notably, tissue segmentation in this context refers to the process of dividing a neuroimage into segments that represent various tissue classes, such as GM, WM, and CSF.[16] Segmentation that is accurate and reliable is critical, as it can be used to diagnose tumors, inflammation, and lesions, as well as make general claims about neuroscience.[16] As such, errors in segmentation can lead to misdiagnoses, among other negative effects. We suggested that for the astronaut population, the misclassification of tissue may cause artifactual claims of volumetric brain changes during spaceflight, and it could explain the inconsistency reported in the literature addressing the issue of volumetric brain changes resulting from space travel.[15]

To properly understand the neurological impact that spaceflight has on the brain, it is necessary to identify the proper imaging modalities to best capture these changes, while also avoiding this misclassification of tissues. Droby and colleagues have suggested using newer scans such as a version of a magnetization-prepared rapid gradient echo sequence utilizing two inversion pulses (MP2RAGE) to obtain greater contrast between tissue types and correct for bias, which has been suggested to outperform the traditional magnetization-prepared rapid gradient echo sequence (MPRAGE) in automated segmentation software.[17–19] Additionally, Viviani and colleagues have provided evidence that the use of a dual-echo MPRAGE can provide better contrast between tissues and therefore improve segmentation accuracy.[20] The DEMPRAGE modality was selected due to the literature support of its high spatial resolution as well as minimal distortion, as a result of its increased readout bandwidth. Research has reported its ability to provide superior GM/dura segmentation, which typically appear similar in commonly used T1-weighted scans,[21,22] and it has been demonstrated to produce more reliable volume estimates for cortical structures as well.[23] Specifically, these two modalities have been suggested to improve the contrast between the dura and the other tissues in the brain.[17,20] In the present study, a BRAin VOlume imaging scan (BRAVO) was chosen as the standard or comparison modality for this research, due to its popularity throughout the literature regarding its tissue contrast and spatial resolution.[24] We hypothesized that these newer modalities may reduce the propensity of artifactual segmentation in the brains of astronauts, therefore improving our knowledge regarding the true impacts of spaceflight on the brain.

METHODS

Subjects

We acquired 20 healthy subjects (age mean/SD = 25.83/5.09 yr, 10 men). Subjects were excluded from this research if they had unremovable metal in their body, were on dialysis, or if they had a history of kidney issues or other serious medical conditions that would put them at an increased risk. From each subject, we collected whole-head MRI data from three different scans acquired on a 3T General Electric Discovery 750 MR scanner at Foothills Medical Centre at the University of Calgary. Subjects signed written informed consent before MR images were acquired, and all features of study design were approved by the Calgary Conjoint Health Research Ethics Board at the University of Calgary (REB21-1942).

Procedure

We acquired subject MRI data using a 3T General Electric Discovery 750 (DV26) MR scanner at the University of Calgary's Foothills Medical Centre. We collected three structural images for use in this study: a BRAin VOlume imaging scan (BRAVO; TR = 6.68 ms, TE = 2.94 ms, TI = 650 ms, FA = 10°, FOV 25.6 cm, 1 mm isotropic voxels, 3 min 44 s acquisition time), which was used as a manufacturer equivalent of the commonly used T1-weighted MPRAGE, a Dual-Echo Magnetization-Prepared RApid Gradient Echo sequence (DEMPRAGE; TR = 916 ms, TE_1 = 2.404 ms, TE_2 = 5.796 ms, TI = 900 ms, FA = 8°, FOV 25.6 cm, 1 mm isotropic voxels, 4 min 31 s acquisition time), as well as an MP2RAGE (TR = 7.176 ms, TE = 2.12 ms, TI_1 = 8 s, FA_1 = 7°, TI_2 = 2.2 s, FA_2 = 5°, FOV 25.6 cm, 1 mm isotropic voxels, 5 min 39 s acquisition time), a variation of the standard magnetization-prepared rapid gradient echo sequence which utilizes two inversion timepoints (**Figs. 1** and **2**).

Tissue segmentation was conducted in a region of interest (ROI) centered around the cerebellar tentorium (**Fig. 3**). The ROI "tentorium" encompasses the medial occipital cortex and cerebellar tentorium, spanning a rectangular prism from MNI −25, −99, −22 to MNI 25, −44, 18, as used by Burles and colleagues.[15] Then, we manually excluded the cerebellum from this ROI, resulting in the ROI depicted in Fig. 3. The cerebellar tentorium is a dural structure which separates the cerebellum from the cerebral hemispheres in the brain and supports the cerebrum from collapsing onto the cerebellum due to the effects of gravity (Fig. 3). On most T1 images of preflight astronauts as

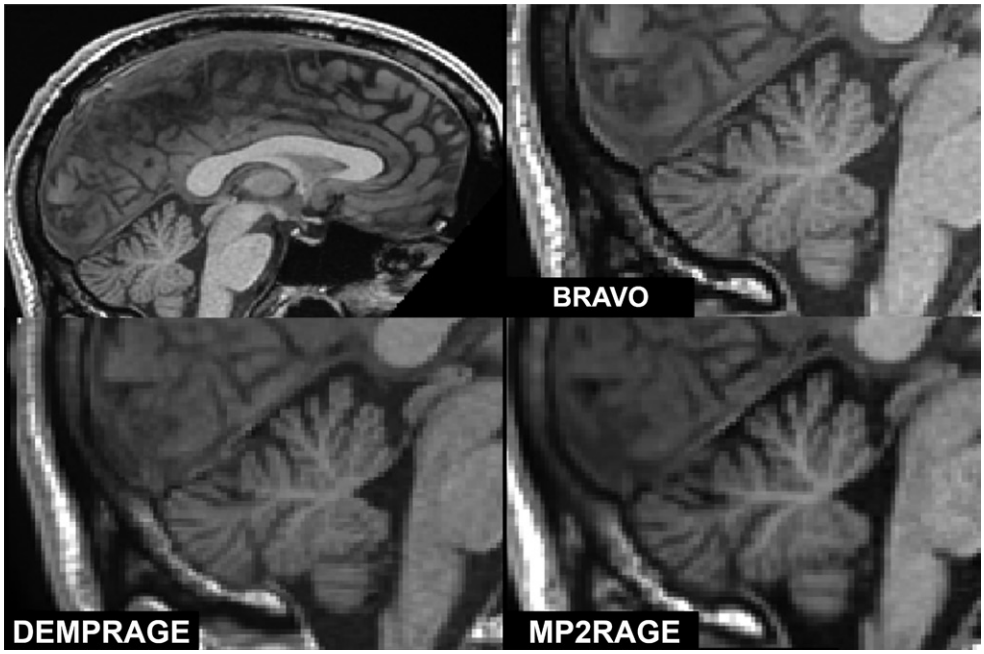

Fig. 1. MR images depict the various modalities collected. Top row depicts BRAVO, bottom left depicts DEMPRAGE, and the bottom right depicts MP2RAGE.

well as the typical research subject, the cerebellar tentorium is often misclassified as GM. The CSF shifts resulting from spaceflight[15] cause the tentorium and cerebral GM to spread apart, as typically the ventral portions of the cerebral cortex rest upon the tentorium. Due to this new space between the tissues, the dural tissue is less likely to be misclassified at postflight timepoints, therefore resulting in incorrect claims of GM losses in astronauts in nearby cortical regions due to spaceflight.[15] We utilized a tentorium ROI that did not include the cerebellum.

GM tissue segmentation was conducted manually by two tracers, L.B. and T.J., in the tentorium ROI. Here, we manually segmented the GM in the tentorium ROI in spaceflight-naive subjects, in which typical automated segmentation algorithms often misclassify large portions of the cerebellar tentorium as GM.[15] Manual GM segmentation was done using the commonly employed software ITK-SNAP[25] in the BRAVO modality of all subjects by both tracers. Manual segmentation of this region was performed to serve as the comparison with the automated segmentation,[26] as manual segmentation has been known throughout the literature as the segmentation method prone to the fewest large errors (i.e., systematic bias errors), although extremely labor intensive.[27]

After manual segmentation, we then utilized automated segmentation procedures from several software tools (Statistical

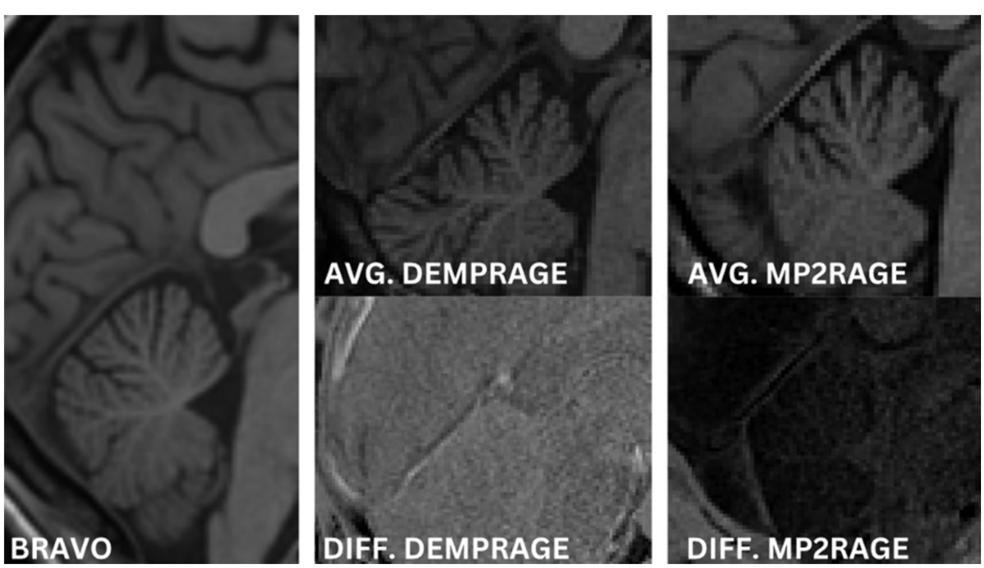

Fig. 2. MR images depict various modalities. The far-left image depicts the BRAVO modality, the top middle row depicts the average DEMPRAGE image combining both TEs, followed to the right by the average MP2RAGE image combining both TIs. The bottom middle row depicts the difference DEMPRAGE image, and the far-right image shows the MP2RAGE difference image. Note that the difference images clearly highlight the tentorium structure.

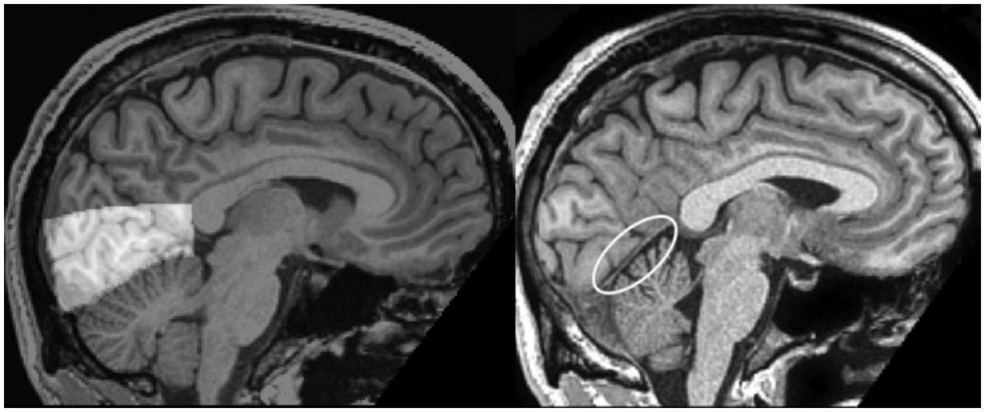

Fig. 3. Images depicting a native-space sample of the tentorium ROI used for tracing and segmentation (left) BRAVO. The right BRAVO image depicts the cerebellar tentorium.

Parametric Mapping 12 [SPM12], FSL 6.0.6, Freesurfer 7.2.0, and Advanced Normalization Tools [ANTs] 2.4.2) for comparison against manual segmentation. Generally, we utilized default or commonly reported settings with minimal adjustment to characterize naive performance of these algorithms with different imaging modalities.

SPM12 unified segmentation module[28] was used to independently segment all image modalities. Sampling distance was set to 1 mm, multiple volumes from the DEMPRAGE and MP2RAGE modalities were included as separate channels.

Images from all modalities were independently brain-extracted using the FSL brain-extraction tool (FSL-BET) with robust brain center estimation. The brain-extracted images were then segmented using FSL's automated segmentation tool (FSL-FAST) with default settings.[27]

Due to Freesurfer's limited capability to process multimodal or multivolume MR images as compared to other software packages, the DEMPRAGE and MP2RAGE four-dimensional images were each combined into three-dimensional volumes for processing. The images from the DEMPRAGE were combined by computing the root mean square value of each voxel across the volumes from each echo.[29] The images from the MP2RAGE modality were combined using the methodology provided by Knussman and colleagues, which multiplied the uniform image with the inversion ("second") image to remove background noise.[30] The unmodified BRAVO and these processed images were then segmented using Freesurfer's recon-all command, with no additional parameters. The cortical ribbon images output by recon-all were used as native-space GM segmentations for comparison with other methods. In contrast with the other automated segmentation procedures, the GM output selected from Freesurfer does not include GM from the cerebellum.

In the ANTs pipeline, the first step involved bias-field correcting images using N4BiasFieldCorrection;[31] each volume in the multivolume acquisitions was bias-field-corrected independently. We utilized the antsBrainExtraction.sh script with templates from the OASIS dataset[32] to generate brain masks for each imaging modality for each subject. These masks were then used to constrain segmentation using Atropos, performing a 3-tissue k-means classification.

Prior to analysis, GM probability maps from each MR modality from each segmentation software were binarized using a 0.5 threshold to classify all brain tissue as either GM (1) or nongray matter (0). This results in outputs that mimic the format of the manual segmentation and facilitates their comparison.

Statistical Analysis

Dice coefficients were obtained for each subject across all modalities and automated segmentation software. Dice coefficients were also utilized to quantify the agreement between tracers (**Fig. 4**). The formula for the computation of Dice coefficients is:

$$Dice = \frac{2x|A \cap B|}{|A| + |B|}$$

Dice coefficients are the result of the spatial similarity of two segmentations, and this coefficient attempts to determine the amount of similarity between two (or more) sets of segmented regions or volumes; in the context of neuroimaging, the Dice coefficient is often used to quantify the accuracy of image

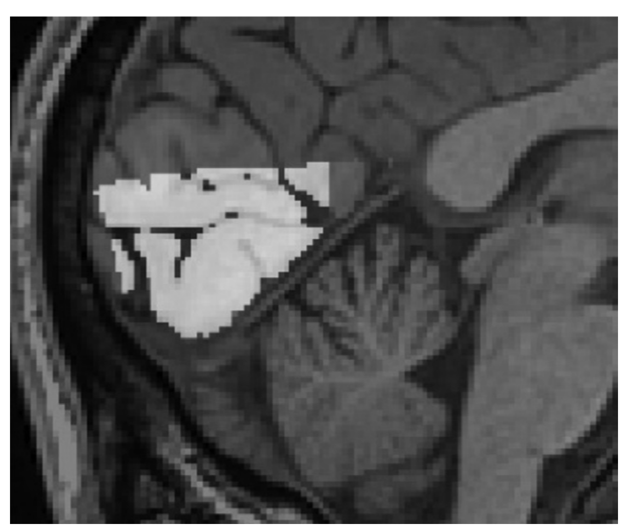

Fig. 4. White region indicative of overlap between manual tracers.

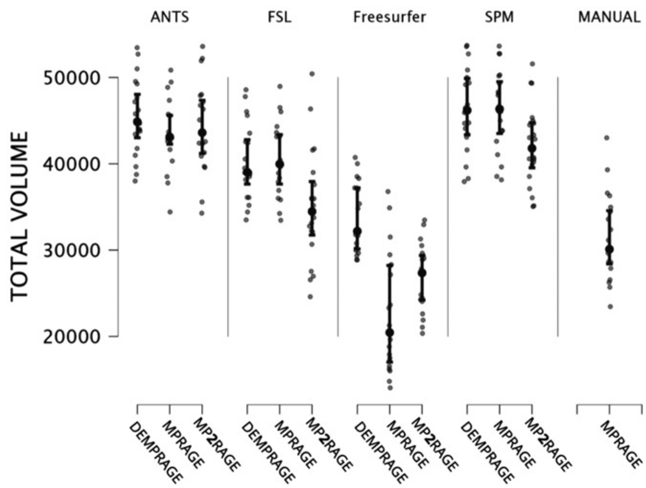

Fig. 5. Flexplot depicts total volume (voxels) estimates across the MPRAGE, MP2RAGE, and DEMPRAGE modalities across the ANTs, FSL, Freesurfer, and SPM12 software. Additionally, total volume estimates for the manual segmentation of the MPRAGE modality are also depicted. Voxels are in cubic millimeters.

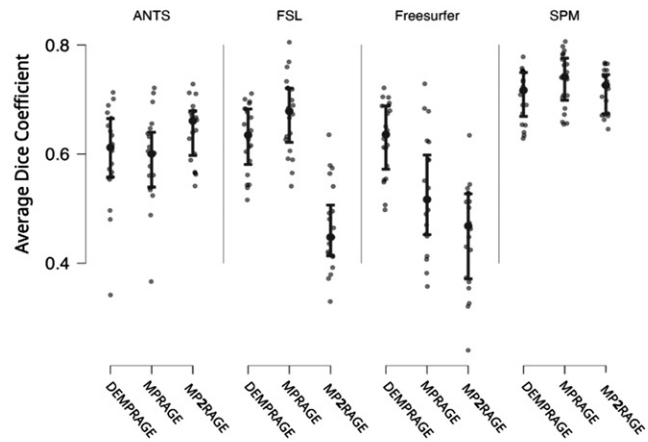

Fig. 6. Flexplot depicts the average dice coefficients for the MPRAGE, DEMPRAGE, and MP2RAGE modalities and between ANTs, FSL, Freesurfer, as well as SPM12 software.

segmentation algorithms, or between two or more tracers.[33] It can be calculated by taking the overlap between the two segmentations divided by the total number of pixels in both images and multiplying this by two, with higher Dice coefficients indicating greater agreement between the segmentations of two or more raters.[33] The total GM volume of the segmentation of the ROI was also obtained from all subjects in all modalities and software to determine the total number of voxels that were classified as GM to determine which automated segmentation software was the most liberal or conservative in their segmentation compared to the manual segmentation (**Fig. 5**). The manual segmentation of the MPRAGE modality reported an average total GM volume of 31,430 voxels (L.B. M = 30,558, SD = 5015 voxels; T.J. M = 32,301, SD = 5915 voxels). In order to compare interrater dice coefficients for all modalities against one another, we conducted two-tailed paired samples *t*-tests between each modality and software program. The significance threshold employed in this study was set at ≤0.05.

RESULTS

Other studies utilizing Dice coefficients conclude that a Dice coefficient above 0.70 represents adequate agreement among individuals, and hence our tracing agreement (M = 0.84, SD = 0.03, MIN = 0.79, MAX = 0.89) is satisfactory and can represent our "ground truth" measure.[34] The average Dice coefficient between both tracers (**Fig. 6**) for the traditional MPRAGE scan was 0.84 (SD = 0.03). This average Dice coefficient suggests that both raters overlapped in their segmentation approximately 84% of all traced voxels. The MPRAGE modality was analyzed across segmentation software, and after statistical comparison with the manual segmentation, it was observed that the segmentation derived from SPM12 was the most similar to manual segmentation for the MPRAGE modality. SPM12 was followed by FSL, ANTs, and then Freesurfer, which was the most unlike manual segmentation (**Table I**). The total ROI GM volume in MPRAGE was highest and therefore most liberal in SPM12, followed by ANTs, FSL, average manual segmentation, and finally Freesurfer with the most conservative GM classification (**Table II**).

The results of a paired samples *t*-test indicated that DEMPRAGE outperformed MP2RAGE when using FSL and Freesurfer, however the opposite was true when using SPM12 and ANTs (**Table III**). The DEMPRAGE modality Dice coefficients were analyzed next, and results indicated that they were significantly less similar to manual segmentation than the MPRAGE modality for SPM12 and FSL. However, DEMPRAGE significantly outperformed MPRAGE in Freesurfer, and nominally outperformed MPRAGE in ANTs as well (Table III). The total GM classification for DEMPRAGE was most liberal again in SPM12 and ANTs, followed by FSL and Freesurfer (Table II).

Finally, results indicated that MP2RAGE was less comparable to the manual segmentation in SPM12 and FSL, as well as Freesurfer. However, in ANTs, the MP2RAGE modality was shown to be more similar to manual segmentation than MPRAGE (Table I). Total volume calculations for the MP2RAGE modality were most liberal using ANTs, followed by SPM12, FSL, and Freesurfer (Table II).

Table I. Average Dice Coefficients Across Software.

	MPRAGE		DEMPRAGE		MP2RAGE	
SOFTWARE	**M**	**SD**	**M**	**SD**	**M**	**SD**
SPM12	0.734	0.05	0.707	0.05	0.717	0.04
FSL	0.671	0.072	0.628	0.062	0.465	0.08
Freesurfer	0.528	0.105	0.628	0.069	0.452	0.097
ANTS	0.591	0.083	0.599	0.089	0.644	0.055
Highest M Dice	SPM12		SPM12		SPM12	

Note: Depicts the average interrater Dice coefficients across modalities and automated segmentation software. The Dice coefficients from SPM12 were highest. The Dice coefficients from SPM12 and FSL were highest for the MPRAGE modality. In Freesurfer, the DEMPRAGE modality resulted in the highest Dice. In ANTs, MP2RAGE resulted in the highest Dice coefficient.

Table II. Total Volume.

SOFTWARE	MPRAGE M	MPRAGE SD	DEMPRAGE M	DEMPRAGE SD	MP2RAGE M	MP2RAGE SD	HIGHEST M VOLUME
SPM12	46, 235	0.05	0.707	0.05	0.717	0.04	DEMPRAGE
FSL	40, 535	0.072	0.628	0.062	0.465	0.08	MPRAGE
Freesurfer	22, 660	0.105	0.628	0.069	0.452	0.097	DEMPRAGE
ANTS	43, 515	0.083	0.599	0.089	0.644	0.055	DEMPRAGE
Manual Average	31, 430	4910.3					
Highest M Volume	SPM12		SPM12		ANTS		

Note: Total volume calculations between modalities and automated segmentation software. The total volume estimates from the MPRAGE and DEMPRAGE modalities were highest in SPM12.

DISCUSSION

This study explored the use of DEMPRAGE and MP2RAGE modalities that were hypothesized to perform more similarly to a "ground truth" manual measure of segmentation,[18–20] resolving a newly established segmentation issue present among astronauts following a spaceflight mission.[15] To test this hypothesis, we compared the performance of automated software versus ground-truth manual segmentations for the three different image modalities. Contrary to our expectations, our results did not establish an obvious MR imaging modality that outperformed across all automated software. Instead, our findings suggest that the traditional MPRAGE modality still outperforms DEMPRAGE and MP2RAGE in terms of similarity to the manual segmentation in the automated software SPM12 and FSL. However, our results did indicate that DEMPRAGE and MP2RAGE perform most similarly to manual segmentation when using Freesurfer and ANTs, respectively. These findings are not surprising, as the literature reports challenges when selecting MR modality for automated segmentation, suggesting that no single methodological approach could be suitable for all images, not all methods could be conceived as equally effective for a particular type of image,[27] and there is no gold-standard software package to be adopted for brain segmentation.[17,35]

In order to determine which modality resulted in the most liberal and conservative GM classification among segmentation software, we analyzed their total volume estimates. Upon examining the results, a pattern emerged indicating that Freesurfer was extremely conservative in GM classification compared to all other segmentation software. One potential explanation for this bias is that although the cerebellum was removed in all ROIs, some cerebellar voxels may have possibly eluded this deletion. Freesurfer may have avoided segmentation of the cerebellum more accurately than others, resulting in less voxels being classified. Hence, it is a possibility that the Dice coefficients were also affected by this conservative bias in GM volume, as on average Freesurfer had significantly lower average Dice coefficients than other software in MPRAGE and MP2RAGE, and only 0.002 from the lowest Dice coefficient for DEMPRAGE. This finding seems to suggest that Freesurfer may have reported less GM on average than other software, or simply was most conservative in its GM classification, resulting in a lower similarity as less GM voxels were reported. Various literature echoes this concern, as some researchers report that Freesurfer underperforms in regard to robustness and consistency of automated segmentation in comparison to other software.[36,37]

Another possible explanation for our results indicating that these newer modalities only perform better in certain software may be that the automated segmentation software we selected had not been developed with the purpose of segmenting these newer imaging modalities.[17] These software were, presumably, developed specifically to segment BRAVO/MPRAGE MR images.[38] Hence, it is possible that the default segmentation parameters used in traditional MPRAGE modality are not optimized for the newer scans and may consequently impact segmentation performance.[15]

This concept was further supported by visually inspecting the newer modalities (Figs. 1 & 2). In Figs. 1 and 2, it appears significantly easier to differentiate the tentorium from the surrounding GM in the newer DEMPRAGE and MP2RAGE modalities than in the traditional modality. This visual observation suggests that image sequence parameter optimization is possible and may improve the accuracy of these newer modalities. The images obtained using default parameters on the GE MRI scanner and could potentially be improved.

As previous research has suggested that general pipelines were sufficient or were vague in their methods of pipeline optimization,[10,20,39] we did not investigate pipeline optimization and utilized default settings for all modalities to provide a

Table III. Dice Coefficient Comparison.

SOFTWARE	MPRAGE > DEMPRAGE *t*	df	*P*	MPRAGE > MP2RAGE *t*	df	*P*	DEMPRAGE > MP2RAGE *t*	df	*P*
SPM12	10.25	38	<0.001***	4.12	38	<0.001***	−3.54	38	0.002**
FSL	6.68	38	<0.001***	12.75	38	<0.001***	12.05	38	<0.001***
Freesurfer	−4.8	38	<0.001***	2.93	38	<0.001***	14.07	38	<0.001***
ANTS	−0.43	38	0.67	−4.81	38	<0.001***	−2.76	38	0.013*

Note: Interrater Dice coefficient *t*-tests among the MPRAGE, DEMPRAGE, and MP2RAGE modalities, and across the SPM12, FSL, Freesurfer, and ANTs modalities. * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

baseline measure of segmentation accuracy. Future research could expand upon the default settings to better optimize segmentation performance in automated software. There are possible adjustments that could improve performance of automated segmentation using the newer DEMPRAGE and MP2RAGE modalities. SPM12 has the option of utilizing Diffeomorphic Anatomical Registration Through Exponentiated Lie Algebra (DARTEL) to improve normalization and segmentation precision, which has been demonstrated to be effective for segmentation research.[10,19,38] Another method to improve segmentation in SPM12 is to alter the number of Gaussians representing each tissue class and empirically determine which is best for each modality. This was recommended by Viviani and colleagues to fully realize the potential of multimodal segmentation, and it will be important to explore models of signal density in which the number of Gaussian components is varied to identify additional features of tissu.[20] In FSL, another potential optimization parameter involves the use of priors as dura is in a similar anatomical location irrespective of modality. Our research did not make use of priors in FSL as its default implementation does not use spatial priors. Finally, computing novel derivatives of raw images may also best capture the extra information DEMPRAGE and MP2RAGE provide, such as average and difference images (Fig. 2). Utilizing this extra information may also provide better segmentation results.

Our study was conceived with the intent of improving brain tissue segmentation accuracy in the astronaut population, however, non-astronaut data were utilized in this research. The primary reasoning for collecting data from non-astronaut subjects involved the challenging nature of sampling the astronaut population. Nonetheless, this factor does not theoretically impact the results or even the generalizability of this work, as the cerebellar tentorium region is error-prone in all individuals due to its proximity to surrounding GM tissue, regardless of occupation.

Another limitation of this work involved the analysis of only one ROI (i.e., the tentorium). Future work should analyze additional ROIs, including the cerebral falx. This dural structure has been, in fact, shown to be impacted by spaceflight specifically, so it would be a key ROI to investigate in data obtained in the astronaut population.[15] Since we have demonstrated in a previous study that spaceflight induces CSF shifts in the brain that cause the cerebral falx to crowd neighboring tissue and results in a similar GM/dura segmentation issue as reported here,[15] an in-depth analysis of the falx ROI may shed light on the impact of this CSF redistribution and tissue-crowding on automated segmentation accuracy. While the tentorium ROI used in this study provided a deeper understanding of the impact of CSF redistribution that results in increased space between dura and surrounding tissues, the falx ROI would indicate the effects of CSF shifts resulting in decreased space between tissue types, potentially reflecting different segmentation inaccuracies.

Another noteworthy limitation of the present study involves the limited MR modalities obtained and analyzed. DEMPRAGE and MP2RAGE were chosen based on previous support in the literature.[17,20] However, there are numerous other MR modalities that may improve the accuracy of automated segmentation performance. One example is the fast GM acquisition T1 inversion recovery (FGATIR), which has been shown to acquire images with higher resolution and sharper delineation of brain regions than T1 or T2 imaging.[40] The drawback of obtaining FGATIR images is the acquisition time, as it takes approximately twice the time to obtain compared to a MPRAGE acquisition time at 3 T.[40,41] Future work should investigate this modality among others that have the potential to resolve these issues possibly without the use of parameter optimization.

Finally, another prospective solution to this issue is to utilize a Gadolinium-based contrast agent (GBCA) during data collection. GBCAs accumulate in the meninges in the outer layer of the blood brain barrier, permitting easier segmentation from GM in T1-weighted images.[42] There is support in the literature for GBCAs in terms of contrast of blood vessels[43] and dura[44] among other tissues such as tumors. One major concession of GBCA use is that it poses a slight potential risk, as it must be filtered out of the body through the kidneys. Hence, certain populations would be ineligible for this contrast such as those undergoing dialysis, as they rarely have been shown to cause kidney damage.[45] Due to this complication, it is unlikely that GBCAs will present the universal solution to this segmentation problem.

Space exploration is a flourishing industry, with more humans going into space than ever before. In accordance with this rapid development and expansion, there is an increased obligation to better understand the impact space travel has on the brain. This work contributes to providing recommendations for those investigating this impact through the analysis of two newer MR modalities among manual tissue segmentation. However, the astronaut population is not the sole population that could benefit from this research since other neurological issues, such as traumatic brain injuries (TBIs), result in CSF changes in the brain.[46] This population is more appreciable, as approximately 1.5 million Americans are diagnosed with a TBI every year.[47] MRI is a commonly utilized diagnostic tool for neurological conditions such as TBIs, and hence the implications of this research are critical due to their prevalence. The accuracy of MRI segmentations is significant, as they aid in a clearer understanding of the neurological effects of such a common brain injury.

Patients receiving dialysis treatment are another potential population that could benefit from this research, as CSF volumetric decreases are reported in those undergoing dialysis.[48] This symptom causes similar crowding issues as spaceflight on the cerebral falx, as the space between certain regions decreases, causing segmentation to become increasingly difficult.[15] If individuals receiving dialysis were to sustain a neurological injury, it is very possible that the MRI segmentation would be erroneous. Hence, the research reported in this manuscript has important implications for many individuals and is not limited exclusively to astronauts.

The primary objective of this research was to pinpoint the MR modalities required to understand and solve the segmentation issues present among astronauts. Our findings revealed that advanced MR modalities could be collected to address this issue. However, this could not be the ultimate solution for the segmentation issues detected in the astronaut population, as the scans investigated in our study only improve segmentation in certain automated software. Further investigation needs to be done to determine whether specific parameters or alternative MR modalities could enhance segmentation precision across all major automated software, which would provide a better methodological approach to advance our understanding of the impact of space travel on the human brain.

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Survival After Ditching in Motorized Aircraft, 1989–2022

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INTRODUCTION: Although an unintended aircraft landing on water (referred to as ditching) is a rare event, the potential for occupant injury/fatality increases immediately following the event due to adverse conditions. However, to date, few studies have addressed the subject. Herein, ditching events and post-ditching survival were investigated.

METHODS: Ditchings (1982–2022) in the United States were identified from the National Transportation Safety Board database. Occupant injury severity, aircraft type, pilot experience, flight conditions, and number of occupants were extracted. Poisson distribution, the Chi-squared test (2-tailed), Mann-Whitney U test, and Kruskal-Wallis one-way analysis of variance were employed.

RESULTS: A total of 96 ditchings were identified. A systematic survey was hampered by the lack of a standardized reporting matrix in the reports. In total, 77 reports were included in the analysis. Across all ditchings, 128 of 169 (76%) occupants survived ditching and were rescued. Importantly, the initial ditching event was survived by 95% of all occupants. However, 32 (19%) occupants died post-ditching by drowning (21/32 cases) or for undetermined reasons. Considering probability per ditching event, in 26 (34%) of all ditchings, one or more occupants was/were fatally injured.

DISCUSSION: Initial survival of the emergency ditching is high. Drowning was the leading cause of death after ditching and reduced the overall survival to 76%. Further investigation is needed to identify risk factors for fatal outcomes and/or improve probability of survival after ditching.

KEYWORDS: unintended water landing, fatal injury, drowning, National Transportation Safety Board (NTSB), survival probability, aviation.

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Civil aviation refers to all nonmilitary aviation, including commercial air transportation and general aviation. Commercial air transportation largely comprises scheduled airlines (also referred to as air carriers), while general aviation includes all other civil aviation activities, such as personal and recreational flying, public service missions, charter operations, and agriculture.[1] The majority of general aviation operations involve light (<12,501 lb) single-engine aircraft engaged for the purpose of personal flights.[2]

An unintended landing on a body of water (commonly referred to as ditching) is a rare event in aviation and may be caused by mechanical failure, fuel exhaustion, weather conditions, or human error. To the knowledge of the authors, there is a paucity of research on the subject and likewise few, if any, studies on occupant survivability post-ditching. When operating over an extended body of water, ditching is unavoidable if power is lost and the aircraft is beyond gliding range of land. One question posed in the current study relates to occupant survival surrounding the ditching event itself as well as post-ditching survival. The former is relevant since, upon

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ditching, varying wave height can have considerable effect on aircraft structural integrity and the amount of time it takes for the occupants to exit the aircraft. After ditching, the aircraft might be floating or partially submerged with the risk for rapid sinking. There could be various challenges that occupants face when attempting to evacuate, such as water ingress, structural damage, disorientation, or the need to use emergency exits or procedures that are not used in normal operations, or compromising injury. Additionally, delayed rescue could adversely affect occupant survival, especially if the occupant does not have a flotation device.

The purpose of this retrospective study was to investigate general aviation ditching events (1982–2022) in an area under the jurisdiction of the United States and thus reported on by the corresponding National Transportation Safety Board (NTSB). Survival after ditching and possible influencing factors were investigated.

METHODS

Data were obtained from a retrospective search of the NTSB databases (February 2022 and 1982–2007 releases, available from: https://data.ntsb.gov/avdata). The databases were queried using Boolean search "OR" for events in which the following wildcarded terms included in the "Narr_cause" field were used: ditch, ocean, sea, sunk, sank. Data were exported to Excel and events involving a "ditch" as a synonym for an emergency landing in a ravine/canyon or a catch drain without an actual water landing on an extended body of water were deleted. Merged excel files for the NTSB databases 1982–2007 and 2008–2022 were checked for duplicates.

NTSB electronic reports were downloaded. The following data from the NTSB final reports were used for further analysis: aircraft (engine type, certified maximum gross weight, landing gear type, seats, damage, recovery); pilot (flight time, pilot certification, number of flight crew); environment (flight conditions, light conditions, daytime); occupants (total, injury severity, ditching survival, overall survival); accident location; and rescue and reason for ditching. Occupant injury severity definitions were per 49 CFR 830.2 as extracted from the final NTSB report.[3]

The first step was to investigate the effect of pilot flight experience, the presence of a copilot, and the number of passenger(s) on survival after ditching. In order to exclude scale effects, the flights were categorized with respect to no fatalities or at least one fatality and correlated with the aggregate passenger count (0, 1, or >1 passengers) and the flight experience of the pilots.

Ditching rates can be calculated using total fleet activity data (hours flown) as denominator. The total aviation activity for general aviation (Fleet activity) was derived from the U.S. General Aviation Survey (available from: https://www.faa.gov/data_research/aviation_data_statistics/general_aviation). It represents the sum of fixed-wing and rotary-wing activity (hours) for the periods specified. Rotary-wing fleet activity ranged from 7–15% of total aircraft times over the 1990–2020 period. Fleet activity was used to calculate the ditching rates over the period under review. Since fleet times were only available from 1990 forward, rate analyses could only be determined for that year onward. The current research did not constitute "human subjects research" by virtue of all data being in the public domain. Consequently, institutional review board approval was not required.

Descriptive statistics comprised frequencies for categorical data and median and quartile for metric and ordinal variables. Pearson Chi-squared/Fisher (2-tailed) tests were used to determine whether differences in proportions of categorical variables were, or were not, significant. Continuous variables were analyzed using the Mann-Whitney U test or the Kruskal-Wallis one-way analysis of variance.

Poisson distributions using the natural logarithm of annual fleet times were employed to determine temporal changes in ditching rates over the period specified. *P*-values less than 0.05 were considered statistically significant for all tests. All statistical analyses were performed using SPSS® version 27 (IBM®, Armonk, NY, United States).

RESULTS

Since the search field "narr cause" in the NTSB database was not commonly populated for accidents until 1989, our query period spanned 1989–2021. A total of 96 ditchings were identified over this timespan. All but one of the NTSB's final reports could be downloaded. Screening and exclusions, per **Fig. 1**, allowed for the final inclusion of 77 ditching events in the current study.

Of the aircraft included, 63 (82%) were single engine and 14 (18%) were twin engine. Of the aircraft, 38 (49%) were equipped with retractable landing gear; the median (Q1–Q3) number

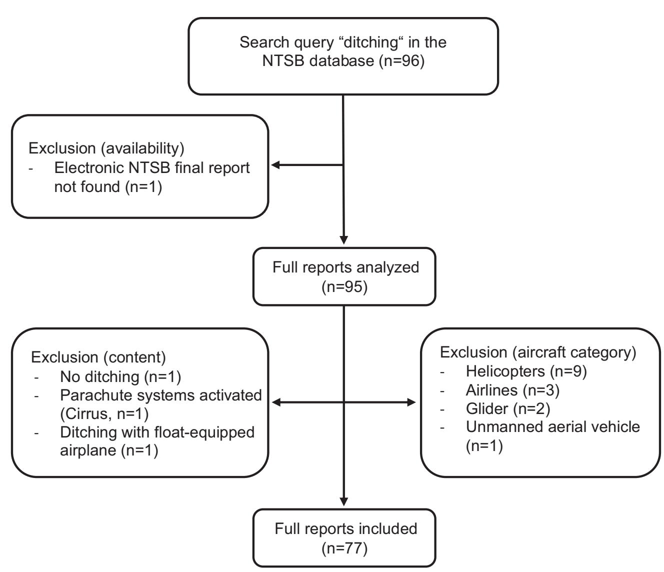

Fig. 1. Flow diagram of the search in the NTSB database and final inclusion of 77 ditching events.

of seats was 4 (3–6). The median (Q1–Q3) certified maximum gross weight of all aircrafts under review was 2925 (2300–3763) lb. Of the aforementioned ditching events, by far the majority were flights with a single pilot (*N* = 71; 92%). On the other flights, the flight crew included a pilot and copilot. Flight attendants were not listed. Approximately half (*N* = 39, 51%) of the ditchings involved flights without passengers, with *N* = 17 (22%) and *N* = 21 (27%) being with one and more than one passenger, respectively. Median (Q1–Q3) flight times of the pilots for all models was 2246 (641–5554) hours. Median (Q1–Q3) flight times for the specific make and model was 250 (91–636) hours.

There were 42 aircraft (55%) that were recovered and could be examined by the NTSB. Neither the passenger count (P = 0.21), the presence of a second pilot-in-command (P = 0.41), nor the pilot's license (private, commercial, or airline transport; P = 0.78) showed a significant effect on fatality rates.

By far the majority of ditching accidents (*N* = 56; 73%) occurred after an event (e.g., loss of power) in the cruise phase of flight. Conversely, ditchings associated with approach and takeoff/climb phases of flight were less frequent, accounting for 8 (10%) and 7 cases (9%) cases, respectively. No significant differences in fatal outcome were found with respect to a specific phase of flight from which the ditching was initiated (P = 0.08). During the evaluation period, a higher number of ditches were evident for the months of July (*N* = 11; 14%) and August (*N* = 10; 13%), although the absence of fleet activities precluded a rate analysis over a calendar year. Of the accidents, 37 (48%) occurred during daylight hours between 11:00 and 15:00 (local time). There were no significant differences in the number of fatalities by time of day (P = 0.84), light conditions (P = 0.73), or month of the year (P = 0.89).

The causes of the ditching events were based on the NTSB reports. There were 29 (38%) classified as mechanical and 23 (30%) had a nonmechanical cause. Due to the low aircraft recovery rate, the cause of the ditching event could not be determined in 25 (33%) flights. When considering ditchings due to nonmechanical causes, fuel exhaustion or starvation was the most prevalent cause in 13 (57%) cases. Carburetor icing, fuel contamination, temporary lack of fuel during maneuvering, and incorrect use of the fuel selector or the fuel shut-off switch represented less frequent causes (each *N* = 2, 9%). The causes of fuel exhaustion were deficient preflight planning or altered flight routes due to navigational difficulties with no refueling facilities or delayed decisions to reroute or request assistance.

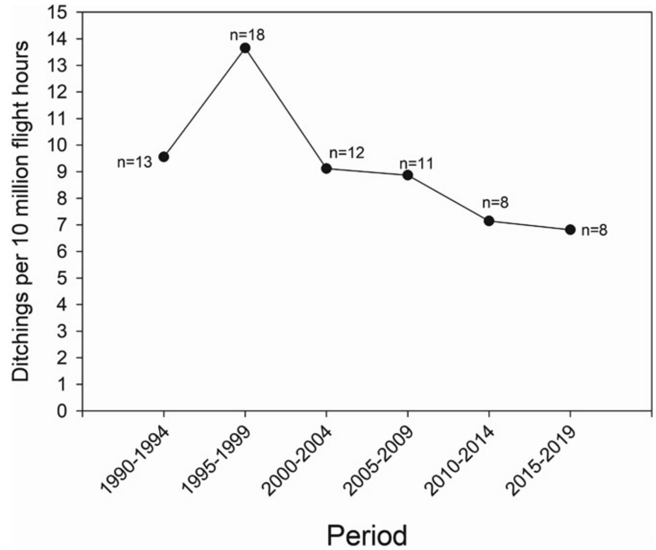

Fig. 2. Ditching rates represent the sum of the fixed-wing and rotary-wing activity over the periods specified. Statistical testing was with a Poisson distribution using the initial period 1990–1994 as referent. Ditching rates did not change significantly over time (P = 0.45).

To determine if ditching accident rates changed over time, a Poisson distribution was used. There were no significant changes in ditching rates over time (P = 0.45, 95% confidence intervals 0.296, 1.722, **Fig. 2**).

Overall, 26 (34%) of the ditchings in the current analysis had a fatal outcome in which one or more occupants perished (**Table I**). Passengers were involved in 16 out of 26 of these ditched flights with at least one fatality. In all of these cases, at least one passenger died (**Table II**). Regarding total occupant count, 128 of 169 (76%) survived the ditching and were rescued. A total of 25 (29%) passengers and 16 (19%) pilots were fatally injured.

The majority of occupants (95%) survived the initial ditching event. For five flights (nine occupants), no information on primary survival was available due to unobserved crash or lack of contact after ditching. However, in total 32 (19%) occupants subsequently succumbed as a result of drowning (21/32 cases) or undetermined causes. Details are shown in Table II.

Ditchings were placed in the context of all types of unintended flight terminations. Therefore, the NTSB database was queried for all aviation accidents between 1982 and 2022. The ratio of fatal accidents to nonfatal accidents for terrestrial accidents was 21% (13,568 fatal vs. 50,804 nonfatal). When

Table I. Survival After Ditching.

DITCHINGS, *N* (%)	≥ 1 FATALITY	OCCUPANTS, *N* [PILOTS/ PASSENGERS, *N*]	SURVIVAL AFTER DITCHING, *N* (%) [PILOTS/ PASSENGERS, *N* (%)]	OVERALL SURVIVAL, *N* (%) [PILOTS/ PASSENGERS, *N* (%)]	MISSING DATA, *N* (%) [PILOTS/ PASSENGERS, *N* (%)]
77 (100%)		169 [83/86]	160 (95%) [78 (94%)/82 (95%)]	128 (76%) [67 (81%)/61 (71%)]	9 (5%) [5 (6%)/4 (5%)]
26 (34%)	Yes	71 [27/44]	62 (87%) [22 (81%)/40 (91%)]	30 (42%) [11 (41%)/19 (43%)]	9 (5%) [5 (6%)/4 (5%)]
51 (66%)	No	98 [56/42]	98 (100%) [56 (100%)/ 42 (100%)]	98 (100%) [56 (100%)/ 42 (100%)]	0 (0%)

Table II. Fatally Injured Occupants by Aircraft Type.

N	AIRCRAFT	OCCUPANTS, N	PILOTS, N	PASSENGERS, N	FATALLY INJURED OCCUPANTS, N	FATALLY INJURED PILOTS, N	FATALLY INJURED PASSENGERS, N
1	Cessna 172	2	1	1	1	0	1
2	Cessna 172 M	1	1	0	1	1	N.A.
3	Cessna 172 P	4	1	3	2	1	1
4	Cessna 177 RG	2	1	1	2	1	1
5	Cessna 195	4	1	3	3	1	2
6	Cessna U206 B	5	1	4	1	0	1
7	Cessna 207 A	1	1	0	1	1	N.A.
8	Cessna 208 B	9	1	8	1	0	1
9	Cessna P210 N	1	1	0	1	1	N.A.
10	Cessna 310 Q	1	1	0	1	1	N.A.
11	Cessna 421 C	4	1	3	4	1	3
12	Chicco Miguel E Quicksilver	2	2	0	1	1	N.A.
13	Johnson Joel H S-6ES Coyote II	2	1	1	1	0	1
14	Maule M-5-235 C	3	1	2	2	0	2
15	Petzel 106 A	1	1	0	1	1	N.A.
16	Piper PA-28-181	1	1	0	1	1	N.A.
17	Piper PA-28-235	2	1	1	2	1	1
18	Piper PA-31-350	5	1	4	1	0	1
19	Piper PA-32	6	1	5	4	0	4
20	Piper PA-32-260	3	1	2	2	0	2
21	Piper PA-32R-301	5	1	4	2	0	2
22	Piper PA-32RT-300T	2	1	1	2	1	1
23	Republic P47 D	1	1	0	1	1	N.A.
24	Temco GC-1B	2	1	1	1	0	1
25	Universal Stinson 108	1	1	0	1	1	N.A.
26	Varga Aircraft 2150 A	1	1	0	1	1	N.A.

comparing ditching and terrestrial accidents, fatality rates were significantly higher after ditching (21% vs. 34%, $P = 0.009$).

Information on lifejackets or flotation devices (whether they were available in cabin, used or not used) was recorded for only 22 (29%) of the NTSB reports. A systematic survey of flotation devices did not exist. It is essential to take into account the potential reporting bias in this context. When reported, lifejackets were worn adequately in seven (32%) and inadequately in another seven (32%) cases. Lifejackets or flotation devices were not used at all in eight (36%). Reasons for inadequate or nonuse of lifejackets range from lack of such devices, inadequate preflight preparation as to their location/retrieval, to insufficient time between ditching and aircraft submersion.

Information on search and/or rescue was available for only 48 (62%) of all cases. Of these, 13 (27%) of all search and rescue attempts were unsuccessful. The occupants of 17 (35%) ditched airplanes were rescued by the U.S. Coast Guard with crew/passengers of 13 (27%) ditched airplanes rescued by other boats or bystanders. For the remainder (five cases, 10%), the occupants swam to shore independently.

DISCUSSION

We report herein that although ditching of general aviation aircraft is rare, when it occurs the probability of surviving the ditching itself is high. Unfortunately, the risk of fatality increases significantly after an initially successful ditching.

Overall, 95% of all occupants survived the primary ditching event. Drowning was described as the predominant cause of death after the ditching in the NTSB's reports and contributed to the overall survival rate of 76% in our study cohort. This is consistent with previous analyses of 40 ditched aircraft from the NTSB database and the International Civil Aviation Organization between 1979 and 1989.[4] The most common cause of injury after ditching (67%) was asphyxiation due to inhalation of water.[5]

After ditching, the aircraft may sink rapidly. Rapid flooding of the cabin and subsequent descent of the aircraft within minutes was reported in another study of 33 ditchings.[4] A preflight briefing, time to prepare for ditching, and a quick and effective evacuation are, therefore, necessary and could increase the chances of survival. After successful evacuation, passengers and crew have to deal with rescue equipment and environmental hazards. In the present survey, passengers were more likely to succumb after a successful primary ditching than pilots. The reasons for this are unclear and we can only speculate that seating position away from an egress point, the pilots' responsibility to ensure that passengers have departed the aircraft prior, unpredictable reactions to stress factors, lack of knowledge in the use of rescue equipment, etc., are all contributory.

Inadequate preflight preparation and flight planning were described in several cases. Areas of bad weather can lead to a change of route and fuel shortages. These factors may lead to critical situations, particularly in low performance aircraft with short glide ranges. Improving pilot training with focus on pre/in-flight planning to prepare for or avoid flying beyond the glide range of land could help prevent ditching events.

The overall fatality rate after ditching was significantly higher compared to terrestrial accidents; however, it is important to remember that ditching is a rare event and represents only a small fraction of all accidents. Overall survival after ditching depends on various factors, including water conditions, availability of survival equipment, and rescue personnel. It is therefore difficult to compare terrestrial and ditching accidents and to make general recommendations.

The descent angle during ditching may affect the impact and could certainly influence outcomes. Unfortunately, there is no information about the descent angle during ditching since there is no information in the NTSB database and many accidents occur without being seen.

Our study was not without limitations. First, the current study is retrospective and only reported and investigated accidents could be included. Second, data analysis was hampered by incomplete data sets. Data extraction was from the final NTSB reports. Achieving data completeness was challenging due to the difficult conditions (ditching offshore, lack of recovery, or absence of witnesses). Third, despite a significant number of presumed drowning accidents, there is no systematic survey of the use of lifejackets or flotation devices in the NTSB reports. A reporting bias must be taken into account and underlines the necessity of further (prospective) investigations. Fourth, the final cause of death could not be determined in all cases for a plethora of reasons, e.g., submerged aircraft, lack of eyewitness reports, or missing bodies. Fifth, fleet activity is the sum of fixed-wing and rotary-wing activity for the periods indicated. The rotorcraft fleet activity ranged from 7–15% of the total aircraft hours over the 1990–2020 period.

While ditching remains a rare event, the probability of a fatal outcome immediately following the event remains high. The main cause of death after ditching was drowning. This was probably facilitated by the difficulty of exiting the aircraft and the rapid descent. Based on our data, the provision and use of flotation devices and the causes of delayed egress from the sinking aircraft need to be studied in detail to reduce fatalities and develop safety recommendations. Further investigation is needed to identify risk factors for fatal outcomes and/or improve probability of survival after ditching.

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Medical Events Encountered at a Major International Airport and Health Services Provided

Mehmet Ali Ceyhan; Gültekin Günhan Demir; Ertan Cömertpay; Yıldız Yıldırımer; Nazlı Görmeli Kurt

INTRODUCTION: Travel by airline starts and ends at airports. Thousands of people consisting of passengers, relatives of passengers, and employees gather at airports every day. In this study, medical events (MEs) encountered at Istanbul Atatürk Airport (IAA) and health services provided were analyzed.

METHODS: The MEs encountered in IAA between January 1, 2016, and December 31, 2018, and health services provided by the private medical clinic in the airport terminal building were retrospectively analyzed.

RESULTS: During the study period, 192,500,930 passengers traveled from the IAA and a total of 11,799 patients were seen at the clinic. There were 4898 (41.5%) male patients. The median age of the 9466 (80.2%) patients whose age was recorded was 34 (28–51) yr. Of 11,799 patients included in the present study, 9228 (78.21%) patients had medical complaints, 1122 (9.5%) patients had trauma complaints, 1180 patients (10%) were transferred to the hospital, and 269 (2.27%) patients required a certificate of preflight fitness. The most common medical complaint was gastrointestinal (1515 patients, 12.84%). The most common trauma was soft tissue injury (345 patients, 2.92%).

DISCUSSION: MEs in airports can be as various and also critical as health conditions seen in emergency departments. It is important to provide medical services with an experienced medical team trained in aviation medicine and adequate medical equipment at airports.

KEYWORDS: airport, air travel, emergency medicine events, prehospital emergencies.

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The number of passengers traveling with airlines is increasing every year for reasons such as transportation speed, comfort, and increased accessibility compared to previous years.[12,13] This increase in passengers is likely to be associated with an increase of accompanying relatives and friends, and an increase of airport employees, potentially leading to an increase of medical events (MEs).[9,18] The identification of MEs encountered at airports will guide future health planning. The present study aimed to analyze MEs encountered at a major international airport, Istanbul Ataturk Airport (IAA), and to demonstrate the health services provided by an airport medical clinic in airport terminal building and the necessity of such a clinic.

METHODS

Subjects

At the time of the study, IAA was the largest airport in Turkey with domestic and international flights. Analysis of MEs encountered and medical services provided in IAA has not been performed so far. This is a retrospective, descriptive, observational study that evaluates the MEs encountered at IAA between January 1, 2016, and December 31, 2018, and the medical services provided by the private medical clinic within the airport. Approval was obtained from the ethics committee of Ankara City Hospital before the study (E.Board-E1-21-1790).

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Procedure

Medical services in IAA were provided by a private medical clinic that provides medical services inside the airport terminal building and campus and 24/7 health services to passengers, accompanying relatives and friends of passengers, and airport personnel. The cost of health care provided by the private health clinic was paid by patients. The medical team consisting of doctors, paramedics, emergency medical technicians, nurses, laboratory technicians, and X-ray technicians was working in the clinic 24/7. X-ray and laboratory services were available in the clinic. MEs in the IAA terminal building are reported to the clinic by security guards, airline staff, and those who witnessed the incident by radio or telephone, and the clinic medical team walks to the scene or travels by ambulance, according to the distance of the local area where the ME occurred. In addition, patients could come to the clinic on their own or be brought over by witnesses of the incident. MEs occurring before takeoff or during flight were reported by aircraft staff to the airport traffic control tower or directly to the clinic and the patient was met at the gate of arrival or aircraft parking apron.

Ambulance transport service was provided to passengers who arrived by air for treatment in hospitals in Istanbul for definitive treatment, who needed to be transported from the airport to hospitals. Similarly, passengers who needed to be transported from the hospital to the airport by ambulance accompanied by medical personnel were transferred to the plane by ambulance. In the present study, this group of patients was categorized as aeromedical evacuation patients. Patients in this category were kept under observation at the airport clinic in cases of flight delay, delayed boarding time, or difficulty in transfer by ambulance, and were treated by airport clinical staff if a new medical condition developed during monitoring. If necessary, certificates of preflight fitness were provided to passengers suffering acute medical events at the airport, or when asked for by the boarding or check-in control team at the airport due to a pre-existing medical condition, by the private clinic located in the airport terminal building.

Electronic medical registration forms were filled out for each patient with information, including demographic characteristics, the place where the incident occurred, complaints, diagnosis and treatment, outcome, and transfer-to-hospital data. Electronic medical records recorded between 2016–2018 were collected from the airport medical clinic. While electronic medical records of patients were taken from the airport clinic, personal information such as patients' identity, addresses, and phone numbers were protected by obscuring. Patient registration forms were retrospectively assessed. Patients with appropriately filled out medical registration forms were enrolled. The examinations of the personnel who applied for routine examination or control other than MEs were excluded from the study. Patients with insufficient data (duplicated or missing parameters, including demographic characteristics, complaints, and the place where the incident occurred) were not included in the study. The demographic characteristics, complaints, outcome, location of the MEs of the patients included in the study, the place where the incident occurred, the medical complaints of the passengers applying for a certificate of preflight fitness, and whether they were ineligible for the flight were analyzed. The MEs were categorized as medical complaints (nontrauma) and trauma. Patients ages 18 yr and over (including 18 yr old) were considered adult, and patients under the age of 18 were considered children.

Statistical Analysis

Descriptive statistics were used to present the data set. Continuous variables were expressed as median (interquartile range, IQR). Categorical data were shown as frequencies and percentages. Normality of the continuous variables was tested with both calculation of skewness-kurtosis and histogram plots. The Statistical Package for the Social Sciences for Windows, version 22 (IBM, Armonk, NY, United States) was used for the statistical analyses.

RESULTS

During the study period, 192,500,930 passengers traveled from IAA and a total of 11,799 patients were seen at the clinic. There were 4898 (41.5%) male patients and 4767 (40.4%) female patients. The gender of 2134 (18%) patients was not recorded. Of the patients whose age was recorded, 1039 (10.9%) were pediatric and 8427 (89.02%) were adult. The median age of the 9466 (80.2%) patients whose age was recorded was 34 (28–51) yr.

Of 11,799 patients included in the present study, 9228 (78.21%) patients had medical complaints, 1122 (9.5%) patients had trauma complaints, 1180 patients (10%) were transferred to the hospital, and 269 (2.27%) patients required a certificate of preflight fitness (**Table I**, **Table II**, **Table III**, **Table IV**).

The most common medical complaints, respectively, were gastrointestinal (1515 patients, 12.84%), cardiovascular (1450 patients, 12.28%), and syncope/presyncope/fainted (1217 patients, 10.31%). The most common gastrointestinal complaint was gastroenteritis/food poisoning/nausea or vomiting (972 patients, 8.23%) (Table I, Table III, Table IV). The most common traumas, respectively, were soft tissue injury (345 patients, 2.92%), falls (318 patients, 2.69%), head trauma (177 patients, 1.50%), and superficial laceration-abrasion (120 patients, 1.01%) (Table II, Table III, Table IV).

A total of 51 (0.43%) cardiac arrests happened (13 cardiac arrests happened in aircraft while 38 happened in the airport terminal building). Of the 51patients (0.43%) who required cardiopulmonary resuscitation (CPR), 35 patients were transported to the hospital, 10 patients died at the scene in spite of CPR, and the results of 6 patients were not recorded (Table I, Table III). When medical teams arrived at the scene, eight patients (0.06%) had developed signs of death, were pronounced dead, and no CPR was performed (Table I). Two patients developed respiratory arrest inside an aircraft; however, the outcome for these patients was not recorded, (Table I).

Symptoms of 2365 (20.04%) patients occurred immediately before departure (during passenger boarding, in the aircraft parking area on the apron, in the bellows or gate areas) or

Table I. Medical Complaints.

COMPLAINTS/SYMPTOMS	N	(%)*
Gastrointestinal	1408	(15.2)
Gastroenteritis/food poisoning/nausea or vomiting	952	(10.31)
Abdominal and pelvic pain	233	(2.52)
Gastritis/epigastric pain/reflux/bloating/constipation	200	(2.16)
Gastrointestinal/hemorrhoids, related bleeding, others	23	(0.24)
Syncope/presyncope/feel faint	1164	(12.61)
Cardiovascular	1130	(12.24)
Hypertension/hypotension	697	(7.55)
Chest pain	267	(2.89)
Cardiac arrest	16	(0.17)
Other cardiovascular complaints	150	(1.62)
Infectious	936	(10.14)
Sore throat/flu symptoms/sinusitis/tonsillitis/fever	871	(9.42)
Chicken pox/possible MERS/other contagious disease	14	(0.15)
Soft tissue infection, other infectious complaints	51	(0.55)
Psychiatric (anxiety/panic attack/hysterical reaction, others)	845	(9.15)
Neurological	691	(7.48)
Headache/dizziness	476	(5.15)
Seizures/febrile convulsion	165	(1.78)
Possible stroke/loss or change of consciousness	18	(0.19)
Other neurological complaints	32	(0.34)
Alcohol/drug-related complaints	303	(3.28)
Otolaryngology (epistaxis/earache/barotrauma, others)	289	(3.13)
Musculoskeletal (muscle pain/joint pain/low back pain, others)	284	(3.07)
Respiratory	271	(2.93)
Shortness of breath/asthma/COPD exacerbations	229	(2.48)
Pneumonia/bronchitis/pulmonary edema	40	(0.43)
Respiratory arrest	2	(0.02)
Endocrinology (diabetic/hyperglycemia/hypoglycemia, others)	177	(1.91)
Urological (uretheric colic, urinary tract infection, other)	147	(1.59)
Obstetric/gynecological (pregnancy/possible abortion, others)	137	(1.48)
Allergy (allergic reactions/urticaria)	112	(1.21)
Ophthalmological	43	(0.46)
Postoperative complications	25	(0.27)
Environmental injuries (insect/tick/scorpion bite/sting, others)	19	(0.20)
Deceased patients (death was pronounced or confirmed)	8	(0.08)
Dermatology	7	(0.07)
Others (complaints that do not comply with any system)	475	(5.14)
Patients required aeromedical evacuation	535	(5.79)
Not recorded	222	(2.40)
Total	9228	(100)

COPD: Chronic obstructive pulmonary disease; MERS: Middle East respiratory syndrome. *Percentage rates were calculated using the total number of patients in the table as the denominator.

Table II. Trauma-Related Complaints.

COMPLAINTS/SYMPTOMS	N	(%)*
Soft tissue injury	303	(27.00)
Fall	279	(24.86)
Head trauma	120	(10.69)
Superficial lacerations/abrasions	114	(10.16)
Burns/scald	52	(4.63)
Bone fracture	39	(3.47)
Dressing	37	(3.29)
Strains and sprains	36	(3.20)
Traffic accidents	33	(2.94)
Joint dislocation	28	(2.49)
Fight injury	21	(1.87)
Superficial scalp lacerations	13	(1.15)
Hemorrhage	8	(0.71)
Cat/dog bite/scratches	5	(0.44)
Eye injury	4	(0.35)
Self-harming with a sharp instrument	4	(0.35)
Ring tourniquet syndrome	4	(0.35)
Work accident	3	(0.26)
Deep lacerations/limb arterial laceration	3	(0.26)
Falling from escalator	3	(0.26)
Nasal fracture	2	(0.17)
Foreign body in soft tissue	2	(0.17)
Dental fractures/subluxation	2	(0.17)
Tendon laceration/ligament rupture	2	(0.17)
Electrical injuries/lightning	1	(0.08)
Blunt abdominal trauma	1	(0.08)
Golf cart crash inside the airport	1	(0.08)
Foreign body in respiratory tract	1	(0.08)
Spine trauma	1	(0.08)
Total	1122	(100)

*Percentage rates were calculated using the total number of patients in the table as the denominator.

immediately after landing (in the aircraft parking area on the apron, in the bellows or gate areas). A total of 9428 (79.9%) patients' complaints occurred in the airport campus and other areas within the terminal building. Data about the location of six MEs (0.05%) were missing. There were 7674 (65.03%) patients who were treated at the scene or in a medical clinic inside the terminal building and discharged.

The most common MEs that caused transfer to the hospital were cardiovascular complaints (308 patients, 26.10%) and trauma (286 patients, 24.23%). The cardiovascular complaint that was the most common cause of referral was chest pain (220 patients, 18.64%). The most common trauma that caused transfer to the hospital was possible bone fracture (64 patients, 5.42%) (Table III).

A total of 1795 (15.21%) patients refused treatment and recommendations of medical teams. There were 511 (4.33%) emergency medical incidents cancelled before the arrival of medical teams following notification; in some cases, the patient had left the scene.

Of patients who required a certificate of preflight fitness, 67 (24.90%) patients asked for preflight fitness for pre-existing medical conditions and 202 (75.09%) patients required a certificate of preflight fitness due to acute/subacute MEs. The reasons for applying for preflight fitness due to acute/subacute MEs, respectively, were diseases of the respiratory system (28 patients, 10.4%), infectious diseases (26 patients, 9.66%), and obstetric/gynecological conditions (24 patients, 8.92%) (Table IV). Of the passengers, 23 (8.55%) were ineligible for the flight. The most common reason for ineligibility for flight was infectious diseases (10 patients, 3.71%). The most common infectious disease that was not suitable for the flight was chicken pox (7 patients, 2.60%).

DISCUSSION

The present study documents the wide range of MEs encountered at an airport and might help designing and staffing

Table III. Clinical Complaints of Patients Transferred to Hospital.

COMPLAINTS/SYMPTOMS	N	(%)*
Trauma-related complaints	286	(24.23)
Bone fracture	64	(5.42)
Head trauma	53	(4.49)
Fall/falling from height	45	(3.81)
Soft tissue injury/fight injury	45	(3.81)
Traffic accidents	41	(3.47)
Joint dislocation/amputation	13	(1.10)
Other trauma-related complaints	25	(2.11)
Medical (nontrauma) complaints		
Cardiovascular	308	(26.10)
Chest pain	220	(18.64)
Cardiac arrest	35	(2.96)
Hypertension/hypotension	22	(1.86)
Other cardiovascular complaints	31	(2.62)
Neurological	169	(14.3)
Possible stroke/loss or change of consciousness	83	(7.03)
Seizures/febrile convulsion	68	(5.76)
Dizziness	6	(0.50)
Other neurological complaints	12	(1.01)
Gastrointestinal	94	(7.96)
Abdominal and pelvic pain	59	(5.0)
Gastroenteritis/food poisoning/nausea or vomiting	13	(1.10)
Gastrointestinal bleeding	10	(0.84)
Other gastrointestinal complaints	12	(1.01)
Obstetric/gynecological (pregnancy/delivery/possible abortion/preterm birth, vaginal bleeding, others)	53	(4.49)
Respiratory	49	(4.15)
Shortness of breath/asthma/COPD exacerbations	34	(2.88)
Pulmonary edema, spontaneous pneumothorax, others	15	(1.27)
Syncope/presyncope/feel faint	48	(4.06)
Psychiatric (anxiety, psychosis, hysterical reaction, others)	41	(3.47)
Endocrinology (diabetic/hyperglycemia/hypoglycemia, others)	25	(2.11)
Alcohol-drug related complaints	24	(2.03)
Infectious (fever/flu symptoms/sinusitis/tonsillitis, others)	17	(1.44)
Musculoskeletal	13	(1.10)
Otolaryngology	8	(0.67)
Urological	5	(0.42)
Allergy (allergic reactions/urticaria)	4	(0.33)
Other (complaints that do not comply with any system)	22	(1.86)
Not recorded	14	(1.18)
Total	1180	(100)

COPD: Chronic obstructive pulmonary disease.
*Percentage rates were calculated using the total number of patients in the table as the denominator.

Table IV. Pre-Flight Medical Evaluation.

COMPLAINTS/SYMPTOMS	N	(%)*
Preflight fitness medical evaluation for pre-existing medical conditions	67	(24.90)
Preflight medical evaluation due to acute/subacute MEs.		
Trauma-related complaints	21	(7.80)
Fall/soft tissue injury/superficial lacerations/abrasions	8	(2.97)
Bone fracture	6	(2.23)
Head trauma	4	(1.48)
Other traumas	3	(1.11)
Medical (nontrauma) complaints		
Respiratory	28	(10.40)
COPD/asthma exacerbations/shortness of breath	25	(9.29)
Other respiratory complaints	3	(1.11)
Infectious	26	(9.66)
Chicken pox	14	(5.20)
Fever	6	(2.23)
Sore throat and flu symptoms/sinusitis/tonsillitis	3	(1.11)
Other contagious infectious complaints	2	(0.74)
Urinary tract infection	1	(0.37)
Obstetric/gynecological	24	(8.92)
Psychiatric	22	(8.17)
Neurological	19	(7.06)
Cerebrovascular disease	5	(1.85)
Seizures	4	(1.48)
Headache/dizziness	4	(1.48)
Numbness in a limb	1	(0.37)
Loss/change of consciousness	1	(0.37)
Hemiplegia with tracheostomy	1	(0.37)
Other neurological complaints	3	(1.11)
Gastrointestinal	13	(4.83)
Gastroenteritis/other gastrointestinal complaints	10	(3.71)
Abdominal and pelvic pain	2	(0.74)
Cirrhosis	1	(0.37)
Cardiovascular	12	(4.46)
Post-operative complications	8	(2.97)
Syncope/presyncope	5	(1.85)
Endocrinology (diabetic, hyperglycemia, hypoglycemia, others)	5	(1.85)
Allergy	3	(1.11)
Alcohol-drug related complaints	1	(0.37)
Otolaryngology	1	(0.37)
Ophthalmological	1	(0.37)
Not recorded	2	(0.74)
Other (complaints that do not comply with any system)	11	(4.08)
Total	269	(100)

*Percentage rates were calculated using the total number of patients in the table as the denominator.

medical support facilities for air hubs. In this study, the most common medical complaints were gastrointestinal. As mentioned in previous studies, gastrointestinal complaints are common issues both during and after travel.[3,25] Lo et al. also reported the top three ground-based MEs in airports were associated with neurological, gastrointestinal, and trauma-related conditions.[16] Cummins et al. also reported gastrointestinal complaints as the second most common MEs encountered at the airport and in flight.[7] During travel, infectious or noninfectious causes can lead to gastrointestinal symptoms.[3] Both before and during the trip, provision of advice about preventive medication, dietary precautions (foods, beverages, water-borne risks), and sanitation is recommended.[7,26]

A remarkable finding of the current study was related to psychiatric complaints. It has been reported that stress factors during travel can cause a wide spectra of mental decompensation.[23] Cwinn and colleagues found that psychological complaints account for 5% of the medical incidents at the airport.[8] During the preflight or postflight period, many physiological stresses, the chaos, and the unusual social environment in the airport are possible causes which may be associated with psychological complaints.[6,20,23] Having units to guide and provide support to passengers at airports can minimize the psychological stress to which passengers are exposed.[21]

The number of cardiopulmonary arrest incidents and deceased patients in this study was low and is consistent with previous travel reports.[10,11,19] Cwinn et al. reported a rate of cardiac arrest at the airport about four times higher than the rate found in this study.[8] Public settings are the locations where adult out-of-hospital cardiac arrest occurs the second most frequently.[27] Increased incidence of out-of-hospital cardiac arrest in crowded public transport areas such as airports and railway stations, especially during rush hour, has been reported, and many of these patients are expected to survive with bystander intervention; therefore, availability of medical services on site, automated external defibrillators on platforms or in trains, and maintenance of CPR training are necessary.[11,17,22]

Approximately one-fifth of the MEs (20%) encountered in the present study occurred immediately before the flight (during passenger boarding, in the aircraft parking area on the apron, in the bellows or gate areas) or immediately after the flight (inside the aircraft, during passenger landing, in the aircraft parking area on the apron, at the bellows or gate areas). Lo et al. reported that approximately 90% of emergency medical incidents occurring at the airport occurred at the arrival gate, the departure gate, and in the aircraft.[16] Training of cabin crew, boarding crew, and the check-in control team for detection of passengers who have health problems or are ineligible for the flight might prevent unintended consequences of in-flight MEs, including aircraft diversion or re-entry.

The most common cause of transfer to hospital was chest pain and was consistent with previous reports.[8] Long-distance brisk walks inside the airport terminal building, baggage handling, psychological stressors and excitement, and physiological changes in the in-flight cabin environment can precipitate coronary symptoms.[1,5] Making arrangements for both minimizing stressors that can precipitate coronary symptoms at airports and facilitation of definitive preflight diagnosis of patients with chest pain at the airport clinic might minimize the undesirable effects.

As mentioned in previous studies, the present study also had emergency calls that were canceled when passengers refused medical care.[8] Providing on-site medical care is important in reducing the burden of unnecessary ME calls on local emergency medical services.[8]

There were passengers who came by air to hospitals in Istanbul for the definitive treatment of their disease and had to be transferred by ambulance accompanied by medical personnel or vice versa (in the present study, this group of patients was categorized as aeromedical evacuation patients). After the flight, the stability of these patients may deteriorate due to the in-cabin environment, or they may be kept under observation at the airport clinic due to delays in flight plans or disruptions in the transfer to the hospital by ambulance and may have to be treated by airport clinical staff. In designing and staffing of medical support facilities for air hubs, such patients should also be taken into account.

In the current study, there were passengers who applied for flight eligibility due to their acute or chronic illness, and some of these patients were not medically fit to travel by air. In the current study, respiratory symptoms were the most common reason for applying for medical clearance. Passengers with respiratory disease may be exposed to medical challenges such as hypoxemia and respiratory distress due to the hypobaric cabin environment in aircraft.[4,9] A decision regarding suitability for air travel should consider (careful evaluation) a passenger's respiratory condition and significant comorbidities with history and physical examination.[4] Further assessment by a pulmonologist/respiratory specialist is advised for passengers who are deemed too risky to travel by air.[4]

Moreover, changes in the in-flight cabin environment during travel with the airline can adversely affect passengers who have recently been hospitalized, or have acute or chronic health problems, and the severity of the disease may increase.[2,14,24] Assessment for a certificate of preflight fitness of passengers with health problems before air travel by doctors experienced in aviation medicine might minimize the deterioration of the passengers' health during the flight and prevent possible risks.[2,14,15]

The main limitations of this study were retrospective design and limitation of data with a single airport. The patients who refused service, left the scene, or were referred to the hospital did not have a definitive diagnosis and result. It was not recorded whether the patients were passengers, airport employees, or relatives of passengers. It was not recorded that the health events that occurred inside the aircraft were before takeoff or after landing. Information regarding the initial cardiac rhythm (ventricular fibrillation/pulseless ventricular tachycardia/pulseless electrical activity/asystole) of patients who received CPR or use of automated external defibrillators or witness status of the ME were missing.

In conclusion, airports are places where a large number of people gather every day and can encounter specific MEs. MEs in airports can be as various and critical as health conditions seen in emergency departments. It is important to provide medical services from an experienced medical team trained in aviation medicine (to assess passengers' preflight fitness, to minimize deterioration of passengers' health during the flight, and to prevent possible risks) and to have adequate medical equipment at airports.

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Fatigue Risk Management Preferences for Consumer Sleep Technologies and Data Sharing in Aviation

Jaime K. Devine; Jake Choynowski; Steven R. Hursh

INTRODUCTION: Employees from any type of aviation services industry were asked to give their opinions about the usefulness of consumer sleep technologies (CSTs) during operations and their willingness to share data from CSTs with their organizations for fatigue risk management purposes under a variety of circumstances.

METHODS: Respondents provided information about position in aviation and use of CST devices. Respondents ranked sleep issues and feedback metrics by perceived level of importance to operational performance. Respondents rated their likelihood to share data with their organization under a series of hypothetical situations.

RESULTS: Between January-July 2023, 149 ($N = 149$) aviation professionals responded. Pilots comprised 72% ($N = 108$) of respondents; 84% ($N = 125$) of all respondents worked short- or medium-haul operations. "Nighttime operations" and "inconsistent sleep routines" ranked as the most important issues affecting sleep. "Sleep quality history" and "projected alertness levels" ranked as most important feedback metrics for personal management of fatigue. Respondents were split between CST users ($N = 64$) and nonusers ($N = 68$). CST users did not indicate a strong preference for a specific device brand. The most-reported reason for not using a CST was due to not owning one or no perceived need. Respondents indicated greater likelihood of data sharing under conditions where the device was provided to them by their organization.

DISCUSSION: These results suggest that aviation professionals are more concerned about schedule-related disturbances to sleep than they are about endogenous sleep problems. Organizations may be able to increase compliance to data collection for fatigue risk management by providing employees with company-owned CSTs of any brand.

KEYWORDS: fatigue risk management, consumer sleep technologies, preferences.

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Aviation is one of the most highly regulated industries when it comes to fatigue. The Federal Aviation Administration (FAA), the International Air Transport Association (IATA), the Civil Aviation Safety Authority (CASA), and similar regulatory organizations across the world require commercial airlines and other aviation services organizations to have a fatigue risk management system (FRMS) framework in place to limit exposure to risk in their employees who operate in safety-sensitive positions, such as pilots.[1–3] Regulatory requirements differ by region and sector of aviation. Not all types of aviation industries require an FRMS; many organizations choose to operate under an FRMS framework voluntarily as a safeguard against fatigue risk. Research has shown that aircrew are susceptible to fatigue due to sleep loss, shift work, jet lag, long working hours, high workload, early start times, or stress.[4–6] Apart from the growing body of academic literature that investigates fatigue across all types of flight operations,[5,7,8] many aviation service organizations collect their own objective sleep and performance data during operations to comply with regulatory guidance surrounding fatigue risk,[1–3] or to proactively protect their workforce and/or passengers.

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Historically, research-grade actigraphs have been the device of choice to collect sleep data from crewmembers during flight operations for both the fatigue research community as well as aviation safety departments.[8,9] Recently, many consumer sleep technologies (CSTs) like smart watches, fitness trackers, and mobile software applications (apps) have become popular on the consumer market. While not all CSTs have completed the necessary evaluation to determine accuracy for sleep-wake determination, many CSTs have been tested and shown to track sleep as accurately as traditional actigraphs for the purposes of FRMS.[10,11]

CSTs offer advantages over traditional actigraphy with regards to fatigue risk management on an individual level. CSTs deliver immediate feedback about sleep duration and quality directly to the wearer. CSTs also extract data remotely, meaning that researchers can access information about crewmembers' sleep without needing to be in the same region. The efficacy of CST feedback on sleep hygiene still needs to be rigorously tested to establish scientific accuracy, but is a promising lure to FRMS—a field that focuses on improving real world safety rather than understanding the biological phenomenon of fatigue. CSTs are, therefore, poised to revolutionize fatigue management by facilitating the ease of remote data collection, reducing the burden of data collection on the subject, increasing the window of time during which data can be collected, and providing personalized feedback about fatigue risk management to the wearer.

Aviation professionals have anecdotally expressed a desire to replace traditional actigraphs with their preferred CSTs to collect sleep data for FRMS purposes. However, crewmember preferences for data collection using CSTs, or their willingness to share data from CSTs, has not been investigated beyond anecdotal reports. The fatigue science team at the Institutes for Behavior Resources (IBR) has been conducting a series of surveys about the desirability of CSTs as scientifically relevant sleep tracking tools.[12,13] Previous surveys in this project have focused on the opinions of sleep researchers or general consumers. The goal of the current survey is to establish an estimate of aviation professionals' CST brand preferences, desirability of sleep-tracking features, and willingness to share sleep and activity data with their organizations for the purposes of fatigue risk management. To our knowledge, this is the first report of CST device and data-sharing preferences within a pilot or crewmember population.

METHODS

Subjects

Professional opinions from pilots and crewmembers who routinely travel for work were elicited from across the global aviation community through social media, email, and word of mouth. Any crewmember who works in an aircraft while it is in transit (e.g., pilots or cabin crew) was considered eligible for inclusion; aviation professionals who do not work in an aircraft while it is in transit were not eligible for this survey (e.g., air traffic controllers or ground crew). Efforts were taken to recruit respondents from across the world and across aviation industries by directly contacting regional, national, and international airlines, pilot and crewmember associations, aviation societies, advocacy groups, and unions, as well as the use of social media tags. **Fig. 1** shows a flow chart of subject inclusion based on response criteria. Respondents needed to indicate that they held a position in aviation and needed to respond to at least one survey question related to sleep or CST use to be included in the final analysis. Respondents did not need to complete the entire survey to be included in subsequent analysis but did need to provide at least one viable response to be included. A substantial proportion of respondents indicated a role in aeromedical transport via write-in response. Aeromedical transport,

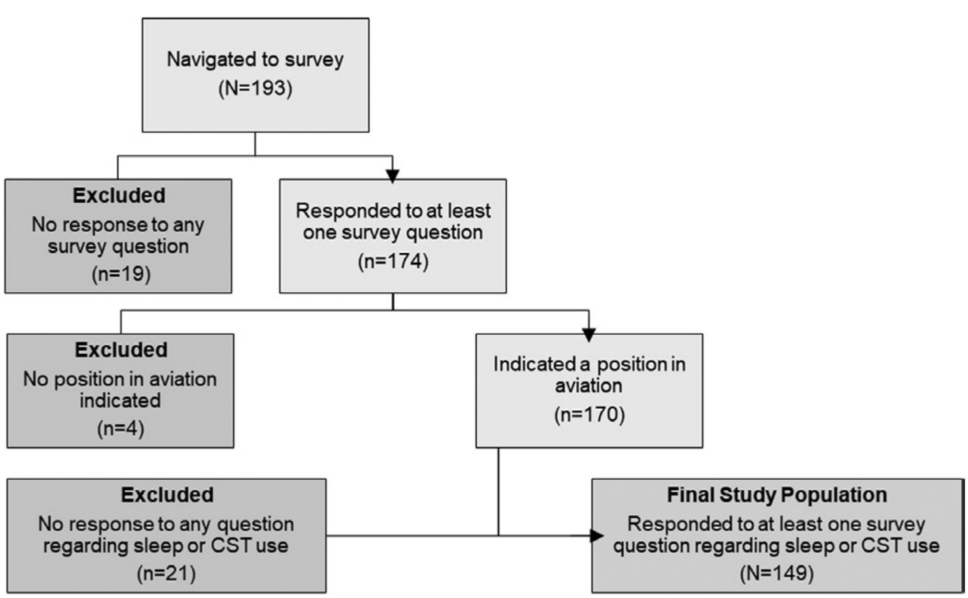

Fig. 1. Flow chart of inclusion and exclusion criteria for survey respondents. High importance is in dark grey; medium importance is in medium grey.

sometimes called air ambulance, medical evacuation (medevac), or helicopter emergency medical services (HEMS), is an emergency medical service that involves the use of an aircraft to move patients from one location to another. An aeromedical transport category was added and examined in subsequent analyses. This study was approved with exempt status by the Salus Institutional Review Board (Protocol Number IBR2023P) and these analyses were conducted in accordance with the Declaration of Helsinki.

Procedure

The survey was hosted on the online tool Qualtrics (www.qualtrics.com). Survey results included in this manuscript were collected between January and July 2023. The voluntary anonymous survey was composed of 11 questions grouped into 3 sections. The first section contained three questions focusing on the respondent's professional demographics (current job position, industry, and length of normal flight operations, in hours).

The second section contained seven questions asking about fatigue, sleep tracking, and device preferences. The last section contained one question asking respondents to rate the likelihood that they would share deidentified data with their organization under the conditions of four separate hypothetical scenarios. Scenarios were developed following discussion with multiple aviation industry fatigue risk managers. Scenarios were based on two of the most common data collection options for FRMS— up to 6 wk of data collection with a sleep diary or a noninteractive sleep tracker (actigraph or CST) and two potential alternative methods of data collection—providing employees with a sleep tracker to keep, or having employees share data from their personally owned sleep tracker. Respondents were able to provide comments in a text box up to a 20k character limit at the end of the survey.

Respondents could select the best fitting option from a multiple-choice list for Q1–Q3 or provide a write-in response if no option described them. Respondents were next asked to rank a list of sleep issues that they felt affected their ability to perform in Q4 and information that helped them manage their own sleep in Q5 by order of importance (high importance, medium importance, or low importance). Respondents could additionally provide and rank a write-in response. Respondents indicated whether they used a sleep tracking device or app in Q6, followed by conditional logic questions asking the respondent to explain why they did or did not use a sleep tracker using a write-in response text box. Respondents next selected their preferred type of sleep tracker for personal use during duty periods in Q7 and ranked the likelihood of providing data (very likely, slightly likely, or not at all likely) under different circumstances in Q8.

Statistical Analysis

All data were exported from Qualtrics as an Excel file and subsequently analyzed using Excel 2013 and STATA MP 15 (StataCorp, College Station, TX, United States). Distribution of responses across job positions, industry, and operation length were tested using the Chi-squared test. The Excel Rank function was used to calculate weighted mean rank order for Q4, Q5, Q7, and Q8 items. Write-in responses for Q6.1a and Q6.1b and Q6.2 were thematically coded using summative content analysis.[14] Subgroup analyses were conducted for respondents within the same job position category or operation length category provided that the group consisted of at least 10% of the total respondent population ($\geq N = 15$) using subject counts, descriptive means and standard deviation, the rank function, and the Wilcoxon signed-rank test for paired samples to determine differences in overall ranking for Q4, Q5, Q7, and Q8 and differences in percentage of CST users and nonusers compared to overall results and between subgroups as appropriate.[15] Statistical significance was assumed at $P \leq 0.05$.

RESULTS

As shown in Fig. 1, the final study population consisted of $N = 149$ respondents. Distribution of respondents by job position, operation length, and organization type is summarized in **Table I**. All respondents completed between 38–100% of the survey, with $N = 72$ respondents completing 100% of the survey. Responses were unequally distributed across job positions ($\chi^2 = 99.86$, $P < 0.001$), industry ($\chi^2 = 158.36$, $P < 0.001$), and normal operation length, defined as short haul (SH), medium haul (MH), long haul (LH), ultra-long range (ULR), or on-call operations ($\chi^2 = 202.23$, $P < 0.001$). As shown in Table I, the greatest number of respondents indicated "pilot" as their job position. Commercial was the most common industry and SH operations were the most common normal operation length.

Rank order responses to Q4–Q5 are depicted in **Fig. 2**. Items are displayed in descending rank order and are numbered by rank. Fig. 2A shows respondents' ranking of important sleep issues that impact their ability to perform work activities. "Nighttime operations" and "inconsistent sleep routine" ranked as the most important. "Jet lag", "snoring/sleep apnea", and "inability to sleep/insomnia" were ranked as the least important sleep factors affecting ability to perform work activities. Fig. 2B depicts perceived importance about information about sleep. Information about "sleep quality history" followed by "projected alertness levels" were ranked as most important for personal sleep management. "Tips for improving sleep hygiene" or "advice on when to exercise or consume caffeine" were ranked as the least important information. Respondents did have the option of entering additional write-in responses for each question but did not name any other sleep issues or information about sleep.

Responses about current CST use, reasons for using or not using a CST, and brand preferences are depicted in **Fig. 3**. As shown in Fig. 3A, 43% of respondents indicated that they currently use a CST. Fig. 3B depicts these respondents' main reasons for using a CST. Sleep and fatigue tracking was the most reported reason for wearing a CST in this group. Fig. 3C shows the main reasons for not using a CST by the 46% of respondents who responded negatively to Q6. No perceived need for a device and simply not owning a device were the most reported reasons in this group. Some respondents provided multiple

Table I. Respondents by Job Position and Operation Length.

JOB POSITION & INDUSTRY TYPE	ON CALL	SHORT HAUL	MEDIUM HAUL	LONG HAUL	ULTRA-LONG HAUL	TOTAL
Pilots						
Commercial	0	23	27	10	3	63
Cargo	0	1	3	1	1	6
Business	0	1	0	1	0	2
Aeromedical	3	27	3	0	0	33
Other	0	4	0	0	0	4
Flight medic						
Commercial	0	0	0	0	0	0
Cargo	0	0	0	0	0	0
Business	0	0	0	0	0	0
Aeromedical	2	27	2	2	1	34
Other	0	0	0	0	0	0
Cabin crew or Other						
Commercial	0	2	2	0	0	4
Cargo	0	0	0	0	0	0
Business	0	0	0	0	0	0
Aeromedical	0	0	0	0	0	0
Other	0	2	1	0	0	3
Totals						
Pilots	3	56	33	12	4	108
Flight medic	2	27	2	2	1	34
Cabin crew or Other	0	4	3	0	0	7
Grand Total	5	87	38	14	5	149

reasons for not using a CST; each reason was independently coded into an appropriate category.

CST users were additionally asked if they had a preferred brand. Largely, respondents did not have a brand preference (30%, $N = 19$). The most frequently named device brand was Garmin (21%; $N = 13$), followed by Apple (17%, $N = 11$), then Fitbit (10%, $N = 6$), Oura ring (6%, $N = 4$), Sleep Cycle (5%, $N = 3$), Samsung (5%, $N = 3$), Whoop (5%, $N = 3$), Google Fit (1%, $N = 1$), and CrewAlert (1%, $N = 1$).

For Q7, $N = 65$ respondents (43%) indicated a preference for a wrist-worn smart watch CST device, followed by a wrist-worn device with no smartwatch capabilities (16%, $N = 24$) or a device worn on the finger (14%, $N = 20$). Less than 10% of respondents preferred a sleep-tracking mobile app like Sleep

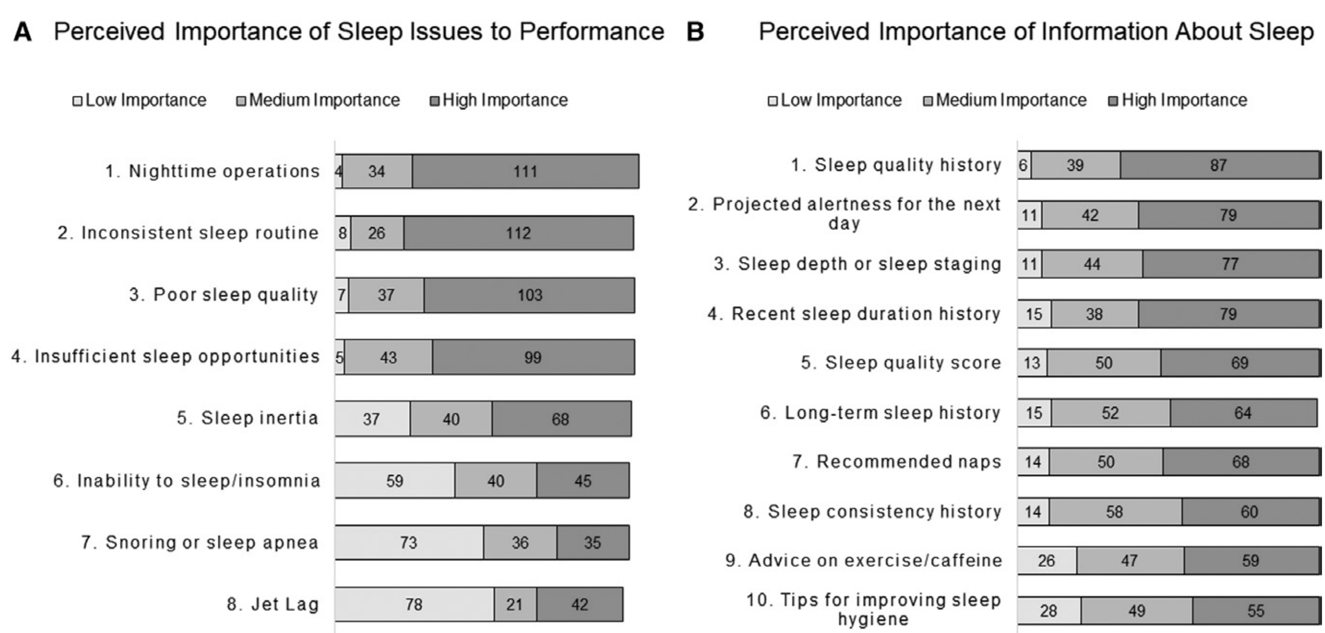

Fig. 2. Perceived importance of sleep issues and information about sleep. Mean rank order of responses regarding A) the level of importance of sleep issues to their ability to perform work tasks and B) the level of importance of information about sleep for personal sleep management. Items are listed on the y-axis by weighted rank, with number 1 corresponding to higher importance ranking. Bars depict the number of responses by level of importance (high importance is in dark grey; medium importance is in medium grey; and low importance is in light grey) for each item.

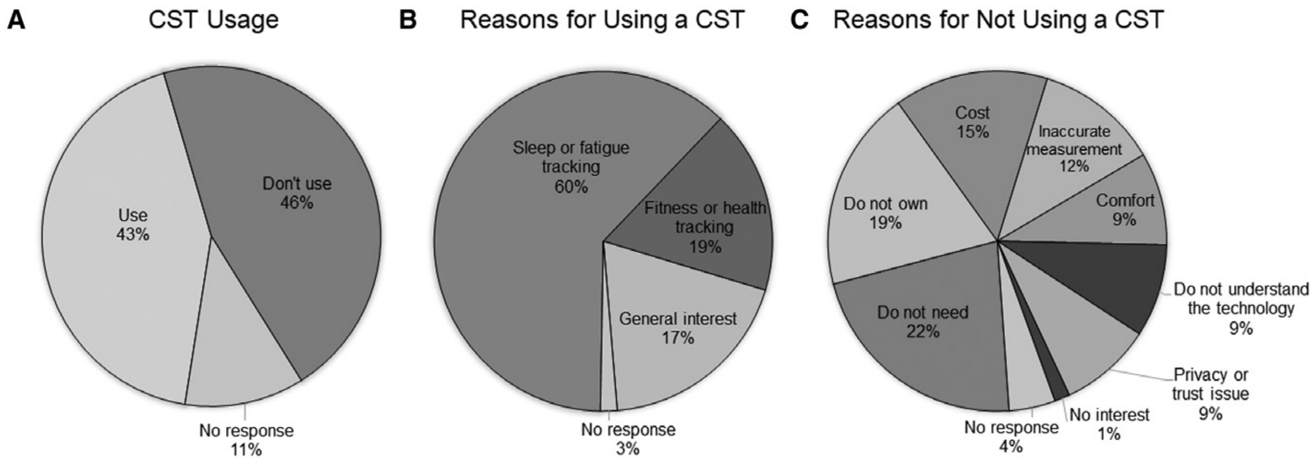

Fig. 3. Consumer sleep technology (CST) usage among aviation professionals. A) Pie chart depicting the percentage of respondents who use a CST, individuals who do not use a CST, and no response. B) Pie chart depicting CST users' reasons for using a CST by theme and percentage. C) Pie chart depicting CST nonusers' reasons for not using a CST by theme and percentage.

Cycle or CrewAlert (6%, $N = 9$), provided a write-in response for continuous positive airway pressure (CPAP) monitoring (1%, $N = 1$), or preferred no device at all (5%, $N = 8$). No respondents indicated a preference for a digital sleep diary or head-worn device. Of the respondents, 14% ($N = 21$) did not provide a response.

Respondents were evenly split between those who reported using a CST ($N = 64$) and those who reported not using a CST ($N = 68$), with no answer at all from $N = 17$ respondents. There were no significant differences between users and nonusers concerning sleep issues that affect performance (Q4; z = 0.00, $P = 1.00$), information about sleep (Q5; z = 0.49, $P = 0.62$), preferences in CST type (Q7; z = 0.00, $P = 1.00$), or data sharing (Q8; z = 0.00, $P = 1.00$). There were no differences in ranking on any question between either CST users or nonusers compared to the overall results (all $P > 0.52$).

Respondents' likelihood to share data with their organizations under different scenarios is summarized in **Fig. 4**. The scenario under which respondents were most likely to provide data was if they were given a sleep tracker to keep indefinitely by their organization. Respondents were least likely to provide data if they were required to complete an electronic sleep diary for up to 6 wk.

Four subgroups met the population threshold ($\geq N = 15$) for subgroup analysis. The pilot subgroup consisted of $N = 108$ respondents while the flight medic subgroup consisted of $N = 34$ individuals. A total of $N = 87$ respondents flew SH operations and $N = 38$ flew MH operations. There was considerable overlap between job positions and normal operation length, such that 52% of pilots ($N = 56$) and 78% ($N = 27$) of flight medics flew SH; 31% of pilots ($N = 33$) and 6% of flight medics ($N = 2$) flew MH. Regarding CST use, 44% ($N = 47$) of pilots and 38% of flight medics ($N = 13$) used a CST; 36% of respondents who flew SH ($N = 31$) and 58% of respondents who flew MH ($N = 22$) used a CST. There were no significant differences in subgroup responses for Q4, Q5, Q7, and Q8 for MH, SH, pilots, or medics compared to overall results between SH and MH, or between pilots and medics (all $P > 0.31$). Due to the overlap in job positions, industries, and operation lengths, no further statistical tests between subgroups were appropriate.

DISCUSSION

Fatigue risk management in aviation depends upon objectively collected sleep and fatigue data that can inform decisions about flight-duty limitations. Research-grade actigraphy has historically been used to collect sleep data for FRMS, but recent advancements in commercial sleep-tracking technology could open up more opportunities for aviation organizations to collect sleep data from crewmembers in a low burden manner. Developing a strategy to update data collection methods for FRMS begins with understanding crewmembers' preferences about CSTs and data sharing. The goal of this survey was to establish which sleep data collection methods would appeal to the greatest number of aviation professionals based on job roles, operation lengths, or specific industry. Importantly, this survey assessed demand for CSTs in aviation professionals in the context of work and FRMS data collection. Thus, findings may not generalize to aviation professionals' preferences about CSTs for personal use.

Overwhelmingly, respondents agreed that the most important sleep issues that impacted their work performance were nighttime operations and inconsistent sleep routine (see Fig. 1A). Circadian misalignment and sleep disruption are considered two major biological factors that contribute to fatigue in aviation.[4,6,7] Aviation FRMS commonly use biomathematical models of fatigue to evaluate the fatigue risk associated with a planned schedule or operation based on sleep loss and circadian misalignment. The aviation industry also takes a proactive approach in educating crewmembers about the causes of fatigue. The findings depicted in Fig. 2A suggest that crewmembers are in agreement with the scientific and risk management communities regarding causes of fatigue that impact performance.

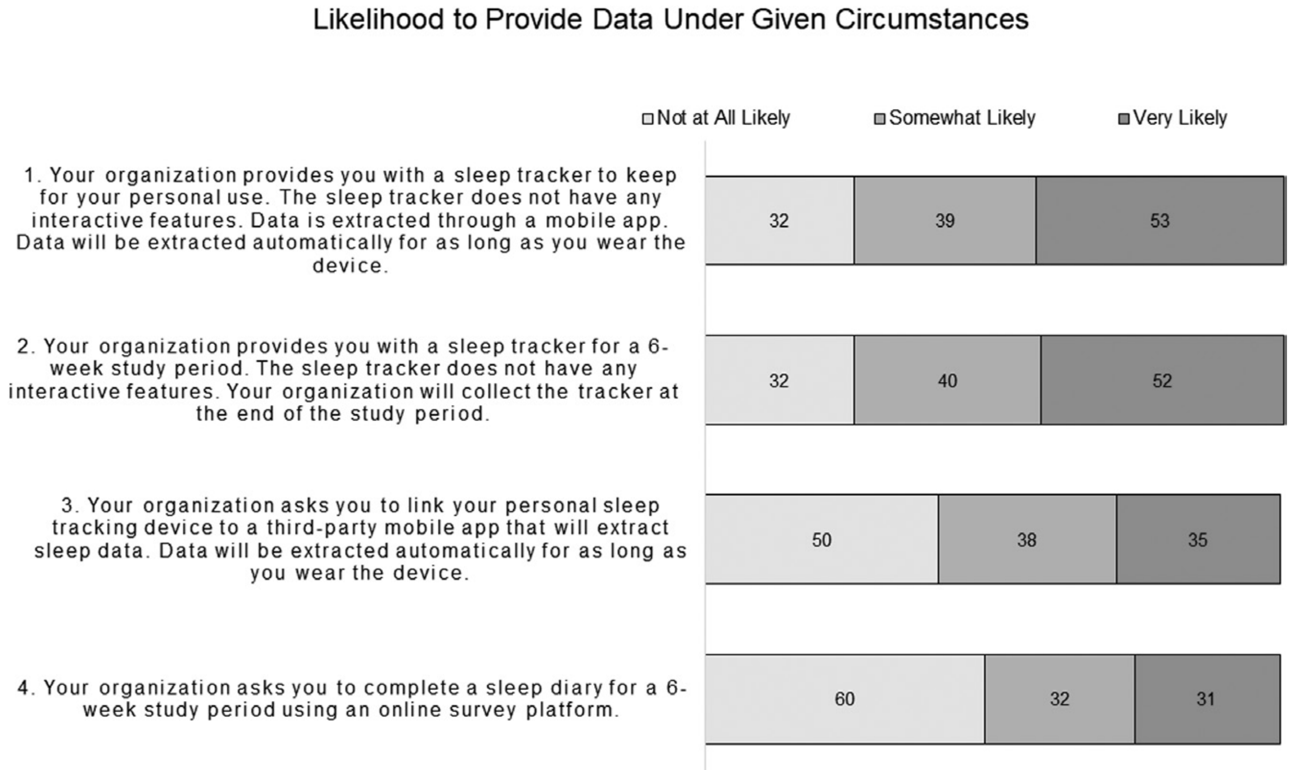

Fig. 4. Likelihood of providing data to organization across circumstances. Mean rank order of responses regarding respondents' likelihood of sharing data with their organization based on the circumstances of data collection. Items are listed on the y-axis by weighted rank, with number 1 corresponding to greater likelihood. Bars depict the number of responses by likelihood (Not at All Likely in light grey, Somewhat Likely in medium grey, Very Likely in dark grey) for each item.

Sleep quality history and projected alertness levels ranked as the most important information for managing sleep, shown in Fig. 2B. Sleep quality may have higher importance than sleep duration to aircrew because their time has schedule constraints. Maximizing sleep quality may be the only option to improve performance during a limited time window that does not allow for longer sleep duration. Inconsistent sleep routines and night-time operations can both lead to diminished sleep quality that can accrue over time. Perhaps information about how well a crewmember slept combined with a prediction of their alertness for the upcoming day is more salient than information about the overall duration of sleep or advice that may not be applicable given their work constraints.

Sleep quality history outranked similar metrics like sleep depth/sleep scoring or sleep quality score. It therefore would seem that sleep quality is viewed separately from sleep depth or sleep scores by the aviation community. Sleep efficiency, or the ratio between the time a person spends asleep over the total time dedicated to sleep, is a common measure of objective sleep quality in the scientific community[16] and could represent what respondents want as feedback about objective sleep quality. Respondents could have been interested in a self-report measure of their own subjective sleep quality. An important follow-up survey would be to investigate the most salient measure of sleep quality over time to provide feedback to aviation professionals.

Another interesting point is that some information that is commonly provided by apps, such as sleep duration or recommendations to improve sleep hygiene, was ranked as having low importance in the current study while projected alertness, which is not a standard metric provided by apps, was ranked second overall. There seems to be a market gap between information that CST developers feel is important to report and information that aviation professionals feel is important to their ability to perform. There are a few mobile apps such as SleepTank,[17] 2BAlert,[18] or CrewAlert[19] that aim to predict alertness in relation to sleep history. These apps have been developed with military or aviation populations in mind, but are not available yet for all platforms or devices.

Interestingly, recommendations about napping, exercise, optimal caffeine consumption, or sleep hygiene tips ranked as the least important perceived information about sleep, as shown in Fig. 2B. This finding seems counterintuitive given the potential benefit that tactical napping, caffeine optimization, exercise, or sleep hygiene techniques may have for an occupational population in a safety-sensitive industry like aviation. It may be that the respondents in this study are unfamiliar with how these techniques may benefit them, have already adopted these techniques, feel that they cannot adequately apply them given the operational constraints of their jobs, or are disinterested in making additional behavioral changes to accommodate their work performance. An interesting follow-up study will be to investigate why aviation professionals viewed actionable advice from a wearable as low value.

Wrist-worn devices were the preferred type of sleep tracker for work purposes. Smart watch sleep trackers and wrist-worn fitness bands with no watch face were selected by a combined 60% of respondents, with devices worn on the finger as the third most popular choice. Aviation professionals frequently sleep in different locations for work, such as an onboard rest facility or a hotel, so a device that can continuously be worn on the body makes practical sense. A previous survey asked real-world sleep researchers their preferences about CSTs and also showed a majority preference for wrist-worn devices, despite the expert respondents reporting "brain activity in combination with motor activity and biometrics" as the most accurate method of measuring sleep.[13] Respondents in the current survey may not be familiar with portable technologies that can measure brain activity, but were provided with the option of a "headband" device on Q7. Respondents in the previous study were members of the sleep research community with experience collecting in the field[13] and, so, were familiar with fieldable CSTs beyond wrist-worn options and were also familiar with compliance problems when working outside the lab.

Wrist-worn devices may be preferrable to real-world sleep researchers because subjects are more likely to wear them consistently. The main goal of a sleep data collection for FRMS is to assess whether the working conditions allow sufficient opportunities for sleep rather than to investigate the biological underpinnings of sleep physiology. Device removal can result in periods of no data that can skew or render the dataset useless. Subject compliance becomes more important than the ability of the device to accurately measure sleep on an epoch-by-epoch basis. The best possible technology may not always be the most accurate technology, but perhaps may be the most convenient technology in some cases.

Device brand loyalty was not strong among CST users, a finding which bodes well for organizations looking to purchase devices for FRMS. This also indicates that there is a market opportunity for CST manufacturers to create a device that can accurately measure sleep in aviation's unique sleeping environment. Only current CST users were asked if they have a preferred device, of whom 30% indicated that they did not have a preference. The most frequently reported devices were Garmin, which were preferred by 21% of CST users ($N = 13$). Five of the reported preferred brands can be categorized as wrist-worn smart watch trackers (Garmin, Apple, Fitbit, Samsung, WHOOP) and one was a ring-based device (Oura). This supports the finding that most aircrew prefer a wrist-worn smart watch CST. Reifman et al. recently showed in a meta-analysis of device validation studies that currently available Fitbit and Oura devices, but not current versions of Garmin or WHOOP, produced sleep measurements that are operationally acceptable for fatigue management.[11] Apple and Samsung devices were not included in that meta-analysis. Three of the preferred trackers were mobile apps (Sleep Cycle, CrewAlert, Google Health) that either require completing a sleep diary or linking the app to a CST. Nonusers' reported "no perceived need", "no device ownership", and "cost" as common reasons for not using a CST, as shown in Fig. 3B. While some nonusers reported concerns about privacy, comfort, the accuracy of the measurements, or unfamiliarity with the technology, these results suggest that nonusers could be convinced to wear a device if they were given one at no personal cost.

The majority of respondents reported high likelihood of providing data through the use of a sleep tracker that has been given to them by the organization. Interestingly, even respondents who were current CST users still preferred to wear a device purchased by the organization over linking their personal device to a third-party data extraction app. Respondents were least likely to provide data through a sleep diary, indicating that if an organization wants to use an app to collect sleep data for FRMS, the app should be able to link to a wearable device. Respondents were not asked if they had ever provided data for FRMS before. This limitation means that we cannot evaluate whether respondents' likelihood ratings were tempered by past experiences. Common methods for data collection in FRMS have been actigraphy or sleep diary for a limited time period (up to 6 wk). It may be that respondents' previous experience with data collection influenced their responses. For example, completing a sleep diary requires more effort on the part of the subject than does wearing an actigraph and can be frustrating. Someone with prior experience as a study subject may have stronger opinions about data collection methods than a respondent who has not done a data collection before.

This report is not without limitations. Responses are not evenly distributed across all sectors of aviation, restricting our ability to compare results with statistical robustness across groups. This is an ongoing study, so efforts will be taken to increase recruitment of survey respondents in meagerly represented categories, such as flight attendants/cabin crew ($N = 7$), LH ($N = 14$), or ULR ($N = 5$) crewmembers. Rank order tests are also qualitative in nature and are most likely not the best method to determine differences between subgroups. These reasons may be why there were no statistical differences in rank order between the overall sample population and subgroups. The results of this survey should be interpreted as preliminary and descriptive. Since the survey is ongoing, follow-up analyses can assess whether there are differences between groups based on position or operation length once a larger number of subjects have responded for each category of interest. Reasons for fatigue are known to differ by operation length,[5,20] so it is important to evaluate fatigue independently across different operational parameters.

Secondly, respondents were not asked to provide information about their region of operation, gender, ethnicity, or level of experience—information that could intersect with issues of fatigue and performance. The recruitment material was also only provided in English and posted on North American-based social media platforms, such as LinkedIn, Instagram, and Twitter/X or live presentation in North America and Europe, which may skew recruitment toward aviation professionals from those regions. Efforts were taken to increase exposure of the recruitment materials to crewmembers globally as well as crewmembers who may identify as an ethnic or gender minority, but these demographic data were not measured by the survey. Therefore, it is impossible to determine between-group differences or gauge the possibility of biased results.

Thirdly, this survey assesses demand in a population that may not fully appreciate the current shortcomings of consumer sleep trackers. Previous surveys in this series have assessed CST demand within a sleep researcher population,[13] as well as demand for scientific accuracy in a CST in a general consumer population,[12] but respondents in this study were not asked about scientific evaluation of CSTs. This was done because any device used for FRMS would need to meet regulatory requirements for validity, so the onus of determining the appropriateness of a device falls on the regulator or operator rather than the individual crewmember. Finally, this survey is tightly focused on sleep-tracking and data sharing, thus it does not encompass the breadth of fatigue issues in aviation. Sleep is a major component of readiness however, so it is our hope that maximizing compliance to data collection within the sleep domain will lead to a better understanding of the impact of fatigue on performance in general.

In conclusion, pilots, flight medics, and cabin crew from commercial aviation, aeromedical transport, cargo aviation, business aviation, and other aviation industries would be more likely to provide sleep data to their organization through a third-party mobile app if they are given a wrist-worn CST to wear by the organization than if they need to link their personal device or complete a sleep diary. Respondents did not indicate strong preferences overall regarding brand loyalty or adopting the use of a CST for FRMS purposes. Crewmembers are most concerned about the impact of nighttime operations and inconsistent sleep routines on their ability to perform and would most appreciate feedback about sleep quality history or predictions about next day alertness. Providing crewmembers with CSTs that simultaneously collect data and provide feedback to improve sleep may doubly benefit FRMS efforts by increasing the flow of information between the organization and the individual worker.

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Re-evaluating the Need for Routine Maximal Aerobic Capacity Testing within Fighter Pilots

Zachary Zeigler; Anthony M. Acevedo

INTRODUCTION: There is a current belief in aviation suggesting that aerobic training may reduce G-tolerance due to potential negative impacts on arterial pressure response. Studies indicate that increasing maximal aerobic capacity ($\dot{V}O_2$ max) through aerobic training does not hinder G-tolerance. Moreover, sustained centrifuge training programs revealed no instances where excessive aerobic exercise compromised a trainee's ability to complete target profiles. The purpose of this review article is to examine the current research in the hope of establishing the need for routine $\dot{V}O_2$-max testing in air force pilot protocols.

METHODS: A systematic search of electronic databases including Google Scholar, PubMed, the Aerospace Medical Association, and Military Medicine was conducted. Keywords related to "human performance," "Air Force fighter pilots," "aerobic function," and "maximal aerobic capacity" were used in various combinations. Articles addressing exercise physiology, G-tolerance, physical training, and fighter pilot maneuvers related to human performance were considered. No primary data collection involving human subjects was conducted; therefore, ethical approval was not required.

RESULTS: The $\dot{V}O_2$-max test provides essential information regarding a pilot's ability to handle increased G_z-load. It assists in predicting G-induced loss of consciousness by assessing anti-G straining maneuver performance and heart rate variables during increased G-load.

DISCUSSION: $\dot{V}O_2$-max testing guides tailored exercise plans, optimizes cardiovascular health, and disproves the notion that aerobic training hampers G-tolerance. Its inclusion in air force protocols could boost readiness, reduce health risks, and refine training for fighter pilots' safety and performance. This evidence-backed approach supports integrating $\dot{V}O_2$-max testing for insights into fitness, risks, and tailored exercise.

KEYWORDS: fighter pilots, $\dot{V}O_2$ max, G_z performance.

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The prevailing belief in the aviation community is that aerobic training will lower overall G-tolerance.[6,9] This thought is perpetuated by the notion that high levels of aerobic training may negatively impact the arterial pressure response, which governs G-tolerance. Despite this prevailing thought, research suggests otherwise. Studies show that aerobic training that increases $\dot{V}O_2$ max will not hinder G-tolerance,[14,37] and it has been found that aerobically trained subjects do not have lower G-tolerance than non-aerobically trained subjects.[23,43] For example, Bateman et al. examined over 500 attendees of a highly sustained centrifuge training program. The authors did not document a single case where excessive aerobic exercise compromised a student's ability to complete target profiles.[3]

The authors intend to provide evidence and create an argument to implement routine $\dot{V}O_2$-max testing into air force pilot protocols. A $\dot{V}O_2$-max test, also known as a maximal oxygen consumption test, measures the maximum amount of oxygen an individual can utilize during intense exercise. It is considered one of the most accurate ways to assess aerobic capacity and overall cardiovascular fitness. The authors have broken down the argument into three points. First, the $\dot{V}O_2$-max test can provide information about the pilot's readiness for duty.

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Second, the $\dot{V}O_2$-max test can give information about the pilot's risk for disease. Third, the $\dot{V}O_2$-max test provides information needed to create a training program tailored to improve aerobic fitness.

METHODS

A systematic search of electronic databases including Google Scholar, PubMed, the Aerospace Medical Association, and Military Medicine was conducted. Keywords related to "human performance," "Air Force fighter pilots," "aerobic function," and "maximal aerobic capacity" were used in various combinations. Articles addressing exercise physiology, G-tolerance, physical training, and fighter pilot maneuvers related to human performance were considered. No primary data collection involving human subjects was conducted; therefore, ethical approval was not required.

RESULTS

The $\dot{V}O_2$-max test provides essential information regarding a pilot's ability to handle increased G_z-load. It assists in predicting G-induced loss of consciousness by assessing anti-G straining maneuver (AGSM) performance and heart rate variables during increased G-load. Additionally, the test can identify cardiovascular risk factors like chronotropic incompetence (CI), abnormal heart rate recovery, and blood pressure (BP) responses.

DISCUSSION

Readiness for Duty

When discussing air force pilots and the cardiovascular (CV) system, much of the talk is around the ability of the CV system to tolerate high G. An inability to have an elevated G-tolerance can lead to G-induced loss of consciousness. An individual's capacity to withstand high G is mainly determined by his/her arterial pressure response to elevated G_z load.[11] It is well-established that the arterial pressure response governs G-tolerance. At increased G_z-load, to maintain arterial pressure in the brain sufficiently high to avoid cerebral anoxia and hence G-induced loss of consciousness, arterial pressure at the heart level must increase to the extent that it overcomes the exaggerated hydrostatic pressure drop along the arteries from the heart.[23] The baroreflexes play an essential role in maintaining this arterial pressure sufficiency.

To help prevent G-induced loss of consciousness, modern fighters are taught to perform the AGSM, which consists of the Valsalva maneuver combined with lower-body muscle strain to avoid blood pooling in the lower extremities. Aerobic training may reduce the effects of fatigue from performing the AGSM, leading to better AGSM performance.[9] AGSM performance is one of the most significant predictors of whether a pilot experiences G-induced loss of consciousness.[41]

In addition to the optimal performance of the AGSM, researchers found many heart rate variables that may shed light on a pilot's ability to handle G_z-load. For example, researchers found that a more minor increase in heart rate during centrifuge training increases the likelihood of failing during high G-training.[41] Moreover, heart rate recovery has been suggested to be an essential factor in tolerating increased G_z-load. Subjects with a higher heart rate reserve (the difference between the maximum and minimum resting heart rate) also presented a more remarkable ability to recover from the orthostatic stress created by the G_z force.[8,13,38] Heart rate and heart rate variability have been shown to help determine a pilot's mental workload.[28] Pilots who failed to increase their heart rate (less than 10%) during the first 1–5 s of 7.5 G-profile had a 10-fold higher chance of failing than those with a more considerable heart rate increase.[40] One variable of interest during an exercise test is heart rate response.

As a pilot performs a standard $\dot{V}O_2$-max test, heart rate is reviewed, and abnormalities can be detected. Peak heart rate could be one of the physiological predictors of G-tolerance during training. Indeed, the heart rate under sustained hypergravity reaches the maximum, depending on the G_z-load, within seconds.[19] Estimating HR_{max} from prediction equations is not ideal due to individual variability. Indeed, the most common estimate equation of HR_{max} is 220 − age,[16] which has been reported to have a standard deviation of 10–12 bpm.[2] Additionally, some data suggests that HR_{max} decreases with aerobic training.[15,45] The proposed mechanisms for this reduced HR_{max} are not entirely understood, but plasma volume expansion and enhanced baroreflex function[47] are thought to play a role. An expanded plasma volume, along with left ventricular cavity enlargement,[44] contributes to increased resting and maximal stroke volume in aerobically trained persons.[1] The decreased HR_{max} is offset by increased stroke volume, thus maintaining optimal cardiac output. These adaptations would not negatively impact arterial pressure response but should function to enhance it. Thus, training for increased cardiorespiratory fitness may favorably impact heart rate response to G_z-loads. For example, a 12-wk conditioning program consisting of 1 h, twice a week, reduced heart rate to a given G-level,[37] suggesting a reduced CV stress. Alternative training methods have proven their effectiveness. Additionally, studies have demonstrated a quicker recovery heart rate following short-interval and high-intensity training sessions.[25] Lastly, syncope, which can occur suddenly during recovery from maximal exercise or even acute exercise, represents a failure to maintain or regulate BP and may be due to reduced muscle pump augmentation of blood return to the right side of the heart.[19] Experimental data has shown that training to increase $\dot{V}O_2$-max increases orthostatic tolerance,[29,31] mainly due to the expanded plasma volume seen from exercise training.[34] The increased orthostatic tolerance derived from increased cardiorespiratory fitness could theoretically aid in tolerating increased G_z-load.

Pilots' Risk for Adverse Events

CVD is one of the most frequent causes of sudden incapacitation in flight for pilots. One study autopsied 534 pilots involved in fatal aircraft accidents from 1996–1999. Cardiovascular abnormalities were found in 44% of them.[39] Additionally, CV risk factors tend to increase throughout a pilot's career. For example, a study looking at German Air Force pilots found that as pilots age, total cholesterol, LDL, glucose, and triglycerides increase significantly.[33] Variables measured during a $\dot{V}O_2$-max test, such as heart rate and BP, have been shown to predict the health and longevity of the participant.

Heart rate response and recovery from maximal exercise provide information about potential CV risk. The need to increase heart rate when exposed to increased G-forces is of paramount importance. CI is the inability to increase heart rate commensurate with exercise demand.[20] CI can be identified during routine $\dot{V}O_2$-max testing. CI can be determined by failure to reach 80% of heart rate reserve, defined as: (observed heart rate max − heart rate rest) ÷ (age-predicted heart rate max − heart rate rest) × 100. Failure to reach 80% of heart rate reserve during a $\dot{V}O_2$-max test has been shown to be a validated method to determine CI.[26] In a study of healthy older adults, it was found that CI was extremely common and is a risk factor for morphological abnormalities of the heart, such as higher left atrium size and left ventricle mass.[24]

A slowed heart rate recovery is associated with all-cause mortality and cardiac events.[30] Heart rate is measured each minute during exercise and 1, 2, 3, and 5 min post-exercise, allowing for this assessment. An abnormal recovery heart rate is a decrease of <22 beats after 2 min of recovery.[36] Cross-sectional data show that $\dot{V}O_2$ max is positively associated with parasympathetic activity,[21] and interval training has been shown to increase parasympathetic activity and baroreflex sensitivity;[32] both could favorably affect heart rate recovery.

BP control is a key factor to pilots withstanding G_z-load. An exercise test can point out if there are abnormalities in BP response. For example, if exercise-induced hypotension takes place, (systolic BP decreases by >10 mmHg with increased intensity), this is a strong predictor of coronary artery disease and ventricular systolic dysfunction[18] and predicts two-year risk for adverse events.[12] On the other end, exercise-induced hypertension, defined as systolic BP > 210 mmHg and diastolic BP > 10 mmHg above resting values, predicts risk for future hypertension and CV events.[18,35] Recovery BP and heart rate also predict future CV issues, and both are assessed during a $\dot{V}O_2$-max test.[35]

Exposure to $+G_z$, particularly on a centrifuge, has been shown to cause premature ventricular contraction, bigeminy, trigeminy, and sinus bradycardia.[7,42,48] Typically, these are benign and resolve upon cessation of the G_z exposure. Although fast jet aircrews are generally healthy, caution is warranted if an individual with underlying cardiac pathology is exposed to increased G_z. Changes in ECG morphology during a $\dot{V}O_2$-max test may indicate underlying pathology. Examples are QRS complexes that are increased, suggesting left ventricular dysfunction, or abnormal ST-segment changes, which have been the standard criteria for coronary artery disease for more than half a century.[35] Lastly, premature ventricular contractions are found in 30–40% of healthy people during an exercise test, and this has been shown to predict 5-yr mortality.[17]

Lastly, aerobic capacity is one of the strongest predictors and prognostic markers for the risk of adverse events in apparently healthy people.[10] For example, those who achieved greater than 10 metabolic equivalents (METs) during a $\dot{V}O_2$-max test have a low prevalence of coronary artery disease compared to those who had less than 7 METs.[4] Additionally, each 1-MET increase in functional capacity has been shown to lead to a 13–15% decreased rate of all-cause death and CV events.[22] As the aerobic capacity of pilots increases, so does their life expectancy and possibly their career.

Exercise Prescription

The assessment of $\dot{V}O_2$ max through a controlled and incremental exercise test serves as a pivotal tool in formulating precise and individualized aerobic exercise prescriptions. $\dot{V}O_2$ max reflects the upper limit of an individual's capacity to utilize oxygen during intense physical activity, providing insights into their cardiovascular fitness and endurance potential. By accurately quantifying an individual's oxygen consumption at maximal effort, exercise physiologists can delineate the optimal exercise intensity, duration, and frequency required to elicit physiological adaptations conducive to improved aerobic performance.[27] This data-driven approach facilitates the development of targeted aerobic exercise programs tailored to an individual's specific fitness level, ensuring that training regimens are both effective and safe. Resistance training has been touted as a modality that increases G-tolerance in pilots, yet some data shows no change in G-tolerance from resistance training programs.[5] A universal training modality and program concerning exercise training and the modern fighter pilot are still elusive. The prescription of aerobic exercise guided by $\dot{V}O_2$-max assessments contributes to the enhancement of overall cardiovascular health, endurance, and metabolic efficiency, thereby promoting sustainable and personalized strategies for physical fitness optimization.

The prevailing belief in the aviation community suggesting that aerobic training might lower overall G-tolerance due to potential negative impacts on arterial pressure response is contradicted by recent research findings. Studies indicate that aerobic training, particularly that which increases $\dot{V}O_2$ max, does not hinder G-tolerance, and aerobically trained subjects do not exhibit lower G-tolerance than their non-aerobically trained counterparts. Moreover, evidence from a comprehensive analysis of over 500 individuals engaged in a sustained centrifuge training program found no documented cases where excessive aerobic exercise compromised a student's ability to complete target profiles.[46] Resistance training, often touted as a means to increase G-tolerance, lacks consistent supporting data. The authors advocate for the inclusion of routine $\dot{V}O_2$-max testing in air force pilot protocols, emphasizing its potential to provide valuable information on readiness for duty, assess the risk for adverse events, and guide the formulation of precise and individualized aerobic exercise prescriptions for optimizing cardiovascular health and endurance. This evidence-based approach can contribute to the development of effective and safe training regimens tailored to the specific needs of modern fighter pilots.

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Photorefractive Keratectomy and Laser-Assisted In Situ Keratomileusis on 6-Month Space Missions

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BACKGROUND: This article documents the stability of photorefractive keratectomy (PRK) and laser-assisted in situ keratomileusis (LASIK) in two astronauts during 6-mo missions to the International Space Station.

CASE REPORTS: Ocular examinations including visual acuity, cycloplegic refraction, slit lamp examination, corneal topography, central corneal thickness, optical biometry (axial length/keratometry), applanation tonometry, and dilated fundus examination were performed on each astronaut before and after their missions, and in-flight visual acuity testing was done on flight day 30, 90, and R-30 (30 d before return). They were also questioned regarding visual changes during flight.

DISCUSSION: We documented stable vision in both PRK and LASIK astronauts during liftoff, entry into microgravity, 6 mo on the International Space Station, descent, and landing. Our results suggest that both PRK and LASIK are stable and well tolerated during long-duration spaceflight.

KEYWORDS: PRK, LASIK, vision, spaceflight.

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This report documents the stability of photorefractive keratectomy (PRK) and laser-assisted in situ keratomileusis (LASIK) in two astronauts during 6-mo missions to the International Space Station (ISS). Launch, 6 mo of continuous spaceflight, extravehicular activities (EVAs), and re-entry create an extremely dynamic spectrum of ocular physiological and anatomical changes that may impact the cornea following refractive surgery. Although one previous report documented the stability of PRK in a spaceflight participant during a 12-d Soyuz ISS mission, there have been no reports on PRK stability during long-duration space flight (LDSF) and no reports of LASIK use during any length of spaceflight. This correspondence suggests that both PRK and LASIK are safe and effective procedures that provide stable vision during launch, 6 mo of continuous spaceflight, and descent, with no visual changes attributable to these procedures.

CASE REPORTS

Astronaut 1, a 44-yr-old white man, had bilateral PRK for myopia in 2009 without complications. His preoperative cycloplegic refractive errors were $-4.25 - 0.25 \times 90$ OD and $-4.50 - 0.25 \times 100$ OS. He had a VISX CustomVue procedure and a standard ablation profile with a 6.0×6.0-mm optical zone and an 8.0-mm ablation zone. He had no operative complications and his postoperative course was uneventful. His spaceflight took place several years following his PRK.

His pre-mission eye examination, performed ~3 mo prior to launch, documented uncorrected distance visual acuities of 20/20 OD and 20/20 OS using Acuity Pro software (AcuityPro, Inc., Elk City, OK, United States). Cycloplegic refraction, performed subjectively using 1% tropicamide, documented refractions of −0.25 sphere OD and −0.25 sphere OS with corrected visual acuities of 20/15 OD and 20/15 OS. Cyclopentolate was not used because of its impact on astronaut vision. The cornea was clear OU. Corneal topography, performed with the Zeiss Atlas corneal topographer (Carl Zeiss Meditec, Dublin, CA,

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United States), was consistent with post-PRK surgery in both eyes. Keratometry, performed with the Zeiss IOL Master (Carl Zeiss Meditec), was 39.66 D at 180 and 40.37 D at 90 OD, and 39.57 D at 174 and 40.18 D at 084 OS. Preflight axial length, performed with the Zeiss IOLMaster, was 25.29 mm OD and 25.48 mm OS. The intraocular pressure (IOP), as measured at 10:00 by Goldmann applanation tonometry, was 10 mmHg OD and 12 mmHg OS. The central corneal thickness, as measured with Zeiss Cirrus OCT (Carl Zeiss Meditec), was 468 μm OD and 496 μm OS. The remainder of the ocular examination, including dilated fundus examination and visual fields, was normal OU.

The Soyuz launch from the Baikonur Cosmodrome in Kazakhstan and docking to the ISS were uneventful, taking less than 2 d. This crewmember had no specific vision complaints in transit to the ISS. Once on the ISS, astronauts live in a near-Earth-normal atmosphere of approximately 14.7 psi with 21% oxygen.

In-flight vision testing was performed on flight days (FD) 30, 90, and R-30 (30 d before return). Distance (15 ft) visual acuity was measured with an onboard laptop using Acuity Pro software (Acuity Pro, Inc., Elk City, OK, United States) and near (40 cm) visual acuity (**Fig. 1**) was tested using a logMAR chart (Precision vision, Woodstock, IL, United States), and results were recorded by a remote guider on the ground. Two different charts were used for each test to discourage memorization. Compared with preflight visual acuity, both distance and near visual acuity remained stable or improved in orbit.

Visual symptoms were evaluated using a comprehensive questionnaire that was completed on FD30, FD90, and R-30. This digital in-flight questionnaire was created by NASA specifically for spaceflight-associated neuro-ocular syndrome ocular surveillance[1] and has been used on prior space missions. The questionnaire assessed visual symptoms, including visual distortions, trouble seeing in dim light, fluctuating vision throughout the day, difficulty with depth perception, double vision, change in visual acuity up close (0–3 ft), change in visual acuity at intermediate distances (3–10 ft), and change in visual acuity at distance (>10 ft). Other than a mild subjective change in distance vision, as documented in the questionnaire, none of these symptoms were reported at any time.

Fig. 1. ISS near visual acuity test.

The return trip from the ISS to Earth occurred ∼6 mo post-launch, took 4 h, and was uneventful with no visual complaints. Postflight testing was performed 5 d after landing and ocular parameters were essentially unchanged from the preflight examination, including IOP (10 mmHg OD and 11 mmHg OS, measured at 10:30), uncorrected distance acuity of 20/15 OU, cycloplegic refractions Plano OD, Plano OS, keratometry 39.61 D at 008, 40.27 D at 098 OD, and 39.52 D at 160, 40.18 D at 070 OS, axial length 25.14 mm OD, 25.37 mm OS, central corneal thickness 468 μm OD and 496 μm OS, and unchanged corneal topography. The remainder of the ocular examination, including dilated fundus examination and visual fields, was normal.

Astronaut 2, a 34-yr-old white woman, had bilateral LASIK for hyperopia and astigmatism in 2013 without complications. Her preoperative refractive errors were +1.75 − 2.25 × 180 OD and +1.75 − 2.75 × 002 OS. She had a VISX CustomVue procedure with a superior corneal flap, 6.0 × 6.0-mm optical zone and a 9.0-mm ablation zone OU. She had no operative complications and her postoperative course was uneventful. Her spaceflight took place several years following her LASIK procedure.

Her pre-mission eye examination, performed ∼6 mo prior to launch, documented uncorrected distance visual acuities of 20/15 OD and 20/20 + OS, and cycloplegic refractions of +0.50 − 0.25 × 40 and +0.75 − 0.75 × 175 with corrected visual acuities of 20/15 OD and 20/15 OS. Visual acuity, cycloplegic refraction, keratometry, IOP, axial length, and corneal thickness were all measured using the same instruments and methods as case 1. The cornea was clear OU. Corneal topography was consistent with post-LASIK surgery in both eyes. Keratometry was 43.72 D at 017 and 44.29 D at 107 OD, and 43.21 D at 177 and 44.35 D at 087 OS. Axial lengths were 23.27 mm OD and 23.35 mm OS. The IOP was 11 mmHg OD and 10 mmHg OS at 1100. The central corneal thickness was 500 μm OD and 497 μm OS. The remainder of the ocular examination, including dilated fundus examination and visual fields, was normal.

The launch took place on a SpaceX Falcon 9 rocket from launch complex 39A at the Kennedy Space Center and the Dragon capsule docked with the ISS less than 2 d thereafter. This crewmember reported no specific vision complaints in transit and once on the ISS lived in a near-Earth-normal atmosphere of approximately 14.7 psi with 21% oxygen.

In-flight testing of visual performance was performed on FD30, FD90, and R-30. As with astronaut 1, distance (15 ft) and near visual acuity was recorded by a remote guider on the ground. Compared with preflight visual acuity, both distance and near visual acuity remained stable in orbit. Visual symptoms were evaluated using the previously described questionnaire and no visual symptoms were reported at any time.

The return trip from the ISS to Earth occurred ∼6 mo post-launch, took 4 h, and was without incident or vision complaints. Postflight testing was performed 5 d after landing and ocular parameters were essentially unchanged from the preflight examination, including IOP (10 mmHg OD and 10 mmHg OS at 11:30), cycloplegic refraction (+0.50 sphere OD, +0.75 − 0.75 × 170 OS), keratometry (43.62 D at 010, 44.50 D at 100 OD, and 43.37 at 175, 44.75 at 085 OS), and corneal topography. Axial lengths were 23.14 OD and 23.24 OS. The central corneal thickness was 502 µm OD and 496 µm OS. The remainder of the ocular examination, including dilated fundus examination and visual fields, was normal.

Both astronauts completed multiple EVAs lasting ~6.5 h. The spacesuits used for the EVAs operate in a microgravity environment at a gas pressure of 4.3 psi (29.6 KPa) and 100% oxygen. Neither astronaut noted any visual changes during their EVAs.

DISCUSSION

The optimal method for the correction of refractive errors in astronauts and cosmonauts has been elusive due to the unique environment of spaceflight. Glasses have been commonly used on Space Shuttle and ISS flights, but in the microgravity environment they can be difficult to correctly position and are prone to fogging and displacement during EVAs. Contact lenses are also commonly used on the ISS, but storage, cleaning, insertion, and the potential for ulcerative keratitis complicate their use.

Over the last 40 yr there has been a gradual evolution and refinement of refractive surgery procedures for the correction of refractive errors. Radial keratotomy, which consisted of multiple radial incisions in the peripheral cornea to flatten the central cornea, was initially performed on millions of myopic patients. However, due to diurnal visual fluctuations and a sometimes pronounced hyperopic shift with altitude exposure from hypoxia-induced peripheral corneal expansion,[6] this procedure was quickly eliminated for use in flight personnel. Also, a recent case report documented the first successful use of an implantable collamer lens to correct refractive error in a spaceflight participant during a 12-d spaceflight.[3] In this procedure, an intraocular lens is surgically inserted through a limbal incision and positioned anterior to the natural lens and posterior to the iris.

Given the long and well-documented history of surgical precision in the use of PRK and LASIK, there are potentially many benefits to these procedures as a method of visual correction in astronauts. Both are currently approved surgical procedures for civilian aviation and all branches of the military. This includes their use by pilots of high-performance terrestrial aircraft. In 2007 NASA approved PRK and LASIK for astronaut selection and retention.

PRK is a nonreversible procedure in which the surface of the cornea is reshaped using an excimer laser to produce a desired refractive error. PRK has been used for the correction of a spectrum of refractive errors, including myopia, hyperopia, and astigmatism, and there has been a gradual refinement in PRK technology over time. Since the optical zone diameter must be at least as large as the entrance pupil to preclude parafoveal glare, the initially small optical zone ablation diameters of 4–5 mm, used in early cases, led to sometimes severe glare, halos, and ghost images that became more prominent with increased pupil size at night. Residual central islands, corneal haze, and myopic regression were also reported with early versions of this procedure. The gradual expansion of the optical ablation zone to 6.00 mm, in conjunction with more precise ablation technology, including higher order aberration correction, has mitigated many of these complications. However, the need for retreatment of residual refractive error following PRK after myopia correction is 6.8% and increases with higher degrees of myopia.[12] Stable vision during high altitude exposure, without diurnal fluctuation, has been demonstrated following PRK[6] and it has a well-documented history of successful use in aviation.[10] It is interesting to note that the PRK cornea does increase in thickness during exposure to hypoxia. However, as in the normal cornea, this corneal expansion occurs uniformly so that the corneal surface maintains its normal refractive power.[6] Documentation of PRK use in astronauts during spaceflight has thus far been limited to a single case report describing one spaceflight participant with bilateral PRK who flew on a 12-d Russian Soyuz mission to the ISS in 2012.[4] Our correspondence documents the first use of PRK in an astronaut during a 6-mo Soyuz LDSF to the ISS.

LASIK is also a nonreversible procedure in which a hinged anterior corneal flap is created with a laser or mechanical blade. This flap is then gently lifted and an excimer laser is then used to reshape the underlying cornea. Thereafter, the hinged corneal flap is repositioned onto the cornea. As with PRK, LASIK is an approved procedure for the correction of refractive error in civilian aviation, all four military services, and NASA. Although LASIK exposure to a hypoxic environment does result in increased central corneal thickness, a trend toward steepening of the central cornea, and a small myopic shift, the magnitude of this shift during normal terrestrial aviation exposure is not clinically significant.[11] There have been no previous reports of post-LASIK individuals participating in spaceflight.

The physiological stress of a rocket launch, acute and chronic exposure to microgravity, EVAs, and the abrupt deceleration of a parachute-assisted landing each have a unique impact on ocular physiology and anatomy not seen during terrestrial flight. These changes, including choroidal expansion, increased IOP, shallowing of the anterior chamber, and globe flattening, have the potential to impact the curvature and stability of the PRK or LASIK cornea. During launch of the Soyuz or SpaceX vehicle, the astronaut is exposed to 3.5–4.5 $+G_x$ of forward acceleration that forcefully pushes the eyes toward the rear of the bony orbit. This rearward "eyeballs in" thrust during the 10-min launch sequence quickly dissipates upon reaching the microgravity environment where the eye rapidly undergoes measurable physiological changes. These changes, during the first 30 s of microgravity exposure, include a sudden rise in IOP of about 20–58%.[8] Head-down tilt[9] and parabolic flight studies[8] suggest that this initial pressure spike results from abrupt choroidal expansion within a rigid globe caused by a microgravity-induced venous stasis that inhibits the normal terrestrial gravity-dependent vortex venous drainage from the highly vascular choroid. The continued, sustained IOP increase during the first days of flight[2] may result from choroidal expansion, increased episcleral venous pressure, orbital pressure on the globe, or a combination of these mechanisms. This increased IOP gradually returns to normal during LDSF possibly because of a compensatory decrease in anterior chamber volume that offsets the volume increase within the choroid.[7–9] In support of this notion, decreased anterior chamber depth was recently reported in astronauts following LDSF.[5] Increased peripapillary choroidal thickness, as measured by OCT, was also documented during early LDSF, persisted throughout the mission, and required 45–90 d after flight to return to normal levels.[5] Wostyn recently hypothesized that the delay in resolution of peripapillary choroidal thickness following LDSF may result from the transudation of fluid from the choroidal vasculature, resulting in some degree of choroidal interstitial edema that may only slowly dissipate following a return to the 1-G environment.[13]

Following LDSF, as the space capsule plummets toward Earth during face-up descent, a deceleration of 3.5–4.5 G occurs, which again drives the globe posteriorly (eyeballs in). The rapid descent is slowed by a series of parachute deployments. Thus, a spectrum of distinctive forces acts upon astronaut eyes from launch, through acute and chronic microgravity exposure and re-entry. The magnitude of these forces, in conjunction with the ocular structural changes associated with LDSF, could potentially impact the relatively thin cornea created by PRK as well as the surgically manipulated LASIK cornea.

The astronauts' post-PRK and LASIK corneas in our report were subjected to an extremely wide spectrum of ocular physiological and anatomical changes. It was not possible to objectively evaluate visual changes that may have occurred during liftoff, ascent into low Earth orbit, EVAs, and descent. However, both astronauts subjectively described excellent vision during all phases of their missions. In both PRK and LASIK corneas there was no significant change in corneal curvature or thickness following LDSF. In the eyes of both astronauts there was a very slight decrease in axial length following their missions, which is consistent with spaceflight-associated neuro-ocular syndrome changes during spaceflight.[13] During their 6-mo exposure to microgravity, both astronauts were exposed to a great spectrum of light conditions and work at variable distances within the ISS. This report suggests that modern PRK and LASIK procedures are safe, effective, and suitable for use by astronauts during LDSF.

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Aerospace Medicine Clinic

This article was prepared by Joseph J. Pavelites II, M.S., B.S., Jelaun K. Newsome, D.O., M.P.H., and Joseph J. Pavelites, M.D., Ph.D.

You are a military flight surgeon assigned to a small military aid station. Reviewing your list of patients for the day, you see that you have a return to duty evaluation for a prospective pilot student who was seen by a local emergency department. As you head to meet the patient, your medic brings a discharge summary from the emergency department. The pilot student was in a single vehicle motorcycle accident over the weekend, and, with a quick glance at the emergency department records, the injuries to the patient appear to be negligible. He was traveling at low speed and the small motorcycle slipped from underneath him while making a turn. It looks like he suffered only minor abrasions to one of his legs.

As you head into the examination room, you introduce yourself to a 26-yr-old healthy-appearing male service member in no apparent distress. He is wearing shorts and a t-shirt, and you can see some mild abrasions on the outside of his left leg. As you discuss his accident, you find out that he was wearing appropriate protective clothing, including a helmet. Further discussion reveals that he had continued the short trip home to clean himself up when a friend noticed that his helmet had some minor scrape marks. Although his only complaint was a "sore leg," his friend was concerned for a possible head injury. Out of an abundance of caution, the service member stated he consented to "get checked out" at the local emergency room, where he received a "CAT scan" of his head and "the docs didn't see any problems."

The physical examination reveals no concerning injuries or dysfunction, and the superficial abrasions are crusted over, healing appropriately, and have no sign of infection. Before you approve the return to duty, which will include starting his first day of aviation training in 3 wk, you take a closer look at his discharge paperwork. The report from the CT scan showed no intracranial abnormalities related to the accident, but there was an incidental finding in the "foramen of Monro." Being a little rusty on your intracranial anatomy, you look up this anatomical structure.

1. What is the foramen (or foramina) of Monro?
   A. An opening of the fourth ventricle at the caudal portion of the roof of the fourth ventricle.
   B. A pair of small openings that connect the lateral ventricles of the brain to the third ventricle.
   C. Small zones lying between the costal and sternal attachments of the thoracic diaphragm.
   D. Foramina in the ventricular system linking the fourth ventricle to the cerebellopontine cistern.

ANSWER/DISCUSSION

1. B. The foramina of Monro are passages between the lateral ventricles of the brain and the third ventricle that allow for circulation of cerebral spinal fluid (CSF).[1] Colloid cysts are most likely to form in the vicinity of this foramen.[2] The foramen of Magendie (a.k.a. the median aperture) connects the CSF-filled spaces of the fourth ventricle and the cisterna magna (a.k.a. the cerebellomedullary cistern).[1] A failure of this foramen to form during gestation can cause a cystic obstruction.[3] The sternocostal triangle (a.k.a. foramina of Morgagni, Larrey's space, sternocostal hiatus, among other names) consists of two zones covered by connective tissue that allow for passage of the bilateral internal thoracic vessels through the anterior abdominal wall. These structures can be a weak point leading to retrosternal hernia.[4] The foramen of Luschka is superior to the foramen of Magendie and presents bilaterally.[1] The foramen of Luschka leads to the cerebellopontine cistern (a.k.a. the pontocerebellar cistern), which is a common site for tumors arising from neurological tissue.[5]

The radiologist elaborates on the incidental finding and states that it is a "sub-centimeter hyperattenuating focus within the foramen of Monro, likely a benign colloid cyst." It is approximately 5 mm in size. Furthermore, the radiologist recommends an MRI of the brain for further evaluation. From your studies, you remember that a colloid cyst is a tumor in the brain that consists of gelatinous material covered by a membrane of epithelial tissue.

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2. Can colloid cysts be a danger to safety in flight?
   A. Yes. Colloid cysts are most often found in the foramen of Monro and can block the flow of CSF.
   B. Yes. They are malignant and very likely to metastasize.
   C. No. They pose little danger as they always remain at an inconsequential size and are only incidental findings.
   D. No. Along with C, they have a good chance of regressing and generally remain insignificant clinically.

ANSWER/DISCUSSION

2. A. As in this case, colloid cysts are most often found incidentally, are asymptomatic, and are commonly positioned in the roof of the third ventricle adjacent to the foramina of Monro. This can occasionally result in sudden obstructive hydrocephalus. It can also present with a thunderclap headache and the dreaded (especially in aviation circles) unconscious collapse. The remaining answers are not accurate. Colloid cysts can cause severe symptoms, as noted above. However, they are benign and can demonstrate slow growth or, more commonly, stability over time (particularly with small asymptomatic lesions), with low recurrence after complete resection.[2,6] While colloid cysts are often an incidental finding, they can cause a range of neurological symptoms secondary to hydrocephalus due to blocking the foramen of Monro. Rapid growth of colloid cysts leading to acute hydrocephalus has been lethal in some cases (such as cyst apoplexy, which is very rare).[7,8] As stated previously, colloid cysts do have the ability to grow over time, although 90% show benign stability and they generally do not regress.

You discuss your concerns with the patient. Unfortunately, you must break the news to him that this incidental finding needs to be worked up before you can agree to return him to duty. You check again to make sure he has no headache or neurologic signs or symptoms. Finding none, you tell the patient that you are going to set up an MRI of the brain. This will be done with and without gadolinium contrast to address a differential diagnosis, including ependymoma, subependymoma, craniopharyngioma, meningioma, choroid plexus papilloma/carcinoma, and neurocysticercosis, to help confirm the identity of the incidental finding and provide data for the appropriate specialists to work on the way ahead. You also state that you will be doing some homework to learn more about colloid cysts and look up how this may affect his flight status.

3. Which of the following is false about colloid cysts?
   A. They comprise up to 17% of primary brain tumors.
   B. They comprise approximately 15–20% of intraventricular masses.
   C. The majority of cases are diagnosed in patients between 20–50 yr of age.
   D. They can contain mucin, hemosiderin, cholesterol, and various ions, giving them a wide range of imaging appearance.

ANSWER/DISCUSSION

3. A. Colloid cysts comprise less than 2% of primary brain tumors. The incidence of colloid cysts of the third ventricle is approximately 0.9 per 1 million, and the prevalence is estimated to be around 1 in several thousand.[9] However, colloid cysts account for approximately 20% of intraventricular primary brain tumors.[2] Most patients are diagnosed with a colloid cyst between the third and fifth decades, but they can also be seen in infancy and childhood.[10] Additionally, they can contain mucin, hemosiderin, cholesterol, and various ions, giving them a wide range of imaging appearance.[11]

As you investigate the subject further, you find that MRI is generally the best modality to confirm the identity of a colloid cyst. As a CT is not as reliable for this task, you see that the radiologist's suggestion for an MRI (with and without gadolinium) will be essential to the workup.

4. Which of the following could be mistaken for a colloid cyst?
   A. Craniopharyngioma.
   B. Pilocytic astrocytoma.
   C. Meningioma.
   D. Hematoma.
   E. All of the above.

ANSWER/DISCUSSION

4. E. All of the above lesions can appear similar to a colloid cyst on imaging.[2]

Concerned that this student pilot's career may be over before it starts, you delve into the aeromedical policies of his service and the sister organizations (International Civil Aviation Organization [ICAO], Federal Aviation Administration [FAA], U.S. Navy, U.S. Army, and U.S. Air Force) for guidance on his possible disposition. Upon reviewing the literature, ICAO is the only one of the five organizations that explicitly mentions colloid cysts. While neither the FAA, U.S. Navy, U.S. Army, nor U.S. Air Force specifically make a statement about colloid cysts with regard to returning to flight duties, they do discuss various benign and malignant tumor policies that may be applicable to this case.

The ICAO Manual of Civil Aviation Medicine, Section 10.5 discusses neurologic neoplasms. It states: "Benign parenchymal growths include ependymoma, choroid plexus papilloma, and colloid cyst (considered a cyst rather than a neoplasm) … The presence of a benign intracranial neoplasm is disqualifying for all classes of medical certification."[12] However, medical certification may be considered after 1 yr of observation if the benign neoplasm is removed and recovery is uncomplicated.[12]

From the FAA standpoint, a special issuance would be needed for medical clearance. The benign brain tumor subsection of Item 46. Neurologic of the Guide for Aviation Medical Examiners would be most applicable. Disposition concerning medical clearance would require deferment for FAA decision. For benign brain tumors not surgically treated, the FAA would require that the examiner submit all pertinent medical records, current neurologic evaluation, MRI brain scans performed no more than 12 mo before the AME exam, and the name, dosage, and side effects of medication(s). If the lesion is surgically treated or resected, in addition to the previous requirements, a neuropsychological evaluation and a 2-yr waiting period will be required.[13]

According to the U.S. Navy Aeromedical Reference and Waiver Guide's section on neurological tumors, "all tumors involving the brain or meninges, irrespective of therapeutic outcome, are [considered disqualifying] with no waiver recommended."[14] The U.S. Army has a similar policy in that "all tumors involving the brain or meninges, irrespective of therapeutic outcome, are permanently disqualifying in class 2, 3 or 4 applicants and require aeromedical suspension in trained aircrew."[15]

The U.S. Air Force has removed the topic of malignant neurological tumors from its waiver guide due to the paucity of waiver submissions and has no mention of the disposition of benign lesions. However, regarding the disposition of cancers in general, the waiver request should only be submitted after "clinical disposition has been completed and all appropriate treatments have been initiated using best current clinical guidelines and recommendations."[16] The Air Force has a 6-mo stability period requirement following cessation of definitive therapies.[16]

Results of the patient's MRI show a well-delineated hyperintensity on T1, with peripheral rim enhancement after the administration of gadolinium, and isointensity on T2 weighted images, confirming the diagnosis of a colloid cyst. There is an absence of ventriculomegaly. As noted by Khanpara et al., "third ventricular colloid cysts are well known for their potential to become symptomatic by creating ventricular obstruction often with serious outcome [through a ball valve effect]."[17] Consultation with an aviation neurologist and a neurosurgeon, taken in context with the service member's applicable aviation medicine regulations, leads to the recommendation of a waiver for this incidental finding. A 5-mm incidental, asymptomatic colloid cyst would have a low likelihood of either radiographic progression or acute/subacute neurologic decline. The neurosurgeon counsels that the chance of 10-yr radiographic progression is 10%, with clinical progression near 0%, for this small (5-mm) asymptomatic lesion without ventriculomegaly.

Of note, his service is amenable to retaining the individual and gives him the option to retrain in a nonaviation position. However, the patient entered the service with the express purpose of becoming a pilot. He requests that you go forward with the waiver application. Along with examinations by a neurologist and neurosurgeon, the waiver workup includes a cognitive baseline assessment to assist with monitoring his condition. Happily, for all involved, his service grants the waiver and requires him to have yearly follow-ups that include a CT or MRI for the next 3 yr.

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MAY 1999

New stimulant modafinil (Institut De Medecine Aerospatiale du Service De Sante Des Armees (IMASSA), B.P.73, Brétigny sur Orge Cedex, France): "Disruptions in wake-sleep rhythms, particularly induced by sleep deprivation, are limiting factors for military personnel in operations. The role of sleep and naps in the recovery of performance is generally accepted. Pharmacological aids, for example hypnotic or stimulant substances, can also be effective countermeasures. Recently, a new stimulant compound, modafinil (MODIODAL®), has also proven effective. Considering the excellent results obtained with napping and modafinil, we have studied the combined effect of these two counter-measures on psychomotor performance under conditions simulating an operational situation. Beneficial effects of a few hours' nap on performance were confirmed. Consequently, naps should be encouraged, even if limited and diurnal. Modafinil, which combines wakening and stimulating properties without any known side effects, was useful for longer periods of sleep deprivation and when there was no real possibility of sleep recovery. Modafinil did not prevent sleep if sleep opportunities were available. The combination of naps and modafinil demonstrated the best cognitive performance during sleep deprivation."[1]

MAY 1974

Cold impact on egress (Royal Air Force Institute of Aviation Medicine, Farnborough, Hampshire, UK): "Experiments were undertaken to obtain a numerical measurement of the effect of cold hands on performance of an emergency egress procedure. The results show that egress times will increase from practised control levels (+10°C) after about 5 min in an environment of -30°C, 8 min in -20°C, and 14 min in -10°C. Egress time is doubled after 14, 37, and 57 minutes, respectively, in the same conditions. The experiments also showed that the duration of cold exposure had important effects on egress performance by an effect other than the lowering of finger surface temperature, which suggests that the cooling of other structures in the hands or forearms may have an important influence on manual performance."[2]

Oxygen impact on memory (Medical Research Council, Applied Psychology Unit, Cambridge, UK): "Twelve men performed a step tracking task involving short-term memory while breathing pure oxygen from a demand-type oxygen mask, while breathing air from the mask, and in a control condition without the mask. A reliable ($p < 0.01$) progressive deterioration over 8 min was found while breathing oxygen, but not in the other two conditions. The progressive deterioration was particularly marked in the most difficult short-term memory condition."[3]

Slides and rafts (Office of Aviation Medicine, Federal Aviation Administration, Washington, DC): "Emergency escape equipment for air transport aircraft was limited to ditching considerations prior to World War II. During the war, the ditching equipment was markedly improved. About the same time, nosegear air transport aircraft began evolving, and escape equipment for land emergencies became necessary. A progression from knotted ropes through rope ladders and canvas slides to inflatable escape slides occurred as aircraft got larger. A concomitant improvement in ditching equipment has occurred as aircraft passenger capacity has increased to the present wide-body models. The next logical step is to combine the emergency escape slide and the life raft in one unit, enabling (1) a significant improvement in deployment efficiency during water emergencies, and (2) a significant overall saving in equipment weight."[4]

MAY 1949

Qualification of pilots (Office of the Air Surgeon, U.S. Air Force, Arlington, VA): "Through a study of the causes of disqualification of applicants for aviation training, some evidence may be gained as to the possible areas of the examination which are too rigid as well as other areas where more stringent rules for acceptance could be instituted …

"Mild refractive errors, non-progressive in nature, flat feet, dental defects, and other such disqualifying factors need be re-evaluated in terms of service longevity and operating efficiency. On the other hand, rigid requirements for demonstrable factors required of military pilots must be maintained. Nasal obstructions, sinusitis, defective color vision, cardiovascular defects, and other organic diseases are such factors where the presence of such defects in a pilot definitely handicaps him in the performance of military flying."[5]

New USAF medical department (Editorial Comment): "The United States Air Force, which has been provided with medical service by the Army, will now have its own medical department. The recently published report of the Eberstadt Committee on National Security Organization, a taskforce of the Hoover Commission on Organization of the Executive Branch of the Government, strongly recommended such action and on May 13 its approval by Mr. Louis Johnson, the Secretary of Defense, was announced …

"The Air Surgeon will be given deserved equality with the Surgeons General of the Army and the Navy in his administration of medical personnel and operation of the hospitals under the command jurisdiction of the Chief of Staff of the Air Force."[6]

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This column is prepared each month by Walter Dalitsch III, M.D., M.P.H. Most of the articles mentioned here were printed over the years in the official journal of the Aerospace Medical Association. These and other articles are available for download from Mira LibrarySmart via https://submissions.miracd.com/asmaarchive/Login.aspx.

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Scholarship Winners Announced

Anita Mantri, Ph.D., Memorial Travel Scholarship

Nina Purvis is a junior doctor in the NHS with an interest in extreme environment physiology and health. Her interest in space medicine stems from her undergraduate and Master's studies in Astrophysics (M.Phys.), which she has amalgamated with a Ph.D. in Cancer Research, studying medicine as a graduate-entry student (M.B.B.S.), and taking a year out to complete a second Master's in Space Physiology and Health. She worked as a Postdoctoral Research Fellow in the United States before medical school. She is now completing her PGY-2 year, with a view to starting her next stage of training in summer 2024.

Dr. Purvis has completed the ESA Space Physician Training Course and UTMB PASM internship, being that year's Shaskan Scholarship winner. She is also a past winner of the Aerospace Speaker's Travel Grant from the Royal Aeronautical Society, the Space Medicine Association's International Scholarship, and the Red Flower Vacation Scholarship. She has additionally won awards for research and presentations. She is currently Junior Chair Elect of the AsMA Associate Fellows Group and has contributed to AsMA and AMSRO over the past 6 years, including judging scholarships, publishing in AsMA's journal, helping organize AMSRO elections, running a lecture series during COVID-19, and being an active member and mentor of the next generation of aerospace medicine.

AsMA International Aerospace Medical Scholarship

Dr. Anthony Rengel is a specialist general practitioner and designated aviation medical examiner from Perth, Western Australia. He is a Fellow of the Australian College of Rural & Remote Medicine, a graduate of the Master of Aviation Medicine from the University of Otago and is currently completing his final semester of fellowship training with the Australasian College of Aerospace Medicine. He holds a Masters in Aviation Medicine from the University of Otago, a Bachelor of Medicine and a Bachelor of Surgery from the University of Western Australia, and a B.Sc., also from the University of Western Australia.

Having been flying since 15 years of age and holding a Commercial Pilot Licence, Anthony has combined a passion for remote health care and aviation into a career in aerospace medicine. This has included running fly-out general practice clinics in rural Western Australia, 8 years as an aviation medical examiner for the Civil Aviation Safety Authority, and, in the last 3 years, as a specialist in aeromedical retrieval for the Royal Flying Doctor Service on a variety of fixed and rotary wing platforms. In 2023, Anthony was appointed as a reservist to the Royal Australian Air Force Institute of Aviation Medicine in Adelaide. Recently, he accepted a position with the Australian Antarctic Division and will soon begin preparation to overwinter at Davis Station for the 2025 season. His long-term goal is to work in the space sector, leveraging his knowledge and experience to assist with the next generation of human exploration. Additionally, he wishes to continue active involvement in the training of the next generation of health and aerospace professionals.

Stanley R. Mohler, M.D., Aerospace Medicine Endowed Scholarship

Dora Babocs is a medical doctor with an aim to make surgical procedures a safe option for future deep-space missions. She is currently serving as a Postdoctoral Research Fellow at UTHealth's Advanced Aortic Research Program. Her journey into the realms of medicine and space exploration began in Szeged, Hungary, where she embarked on her career as a General Surgery resident. Driven by a profound curiosity about the cosmos, she is concurrently pursuing a Bachelor's degree in Astronomy and Planetary Science, just graduated as a space specialist in life sciences, and participated in ESA's Space Physician Training 2023. She also plays an integral role in the Biomedical Engineering Group at the Austrian Space Forum (OeWF), contributing her expertise to Mars analog missions. Additionally, she serves as a scholar-in-residence at iGAINT, European Representative of the International Outreach Committee at AMSRO, and as National Point of Contact for Hungary at the Space Generation Advisory Council, fostering international collaboration in space exploration.

Dr. Babocs was also selected for the *Forbes* 30/30 list in 2024. She leads and participates in multiple international projects and activities related to space surgery and is an author or co-author of 3 peer-reviewed articles, 11 other articles, and 2 book chapters. In 2022, she was awarded the Keck Medicine of USC Travel Scholarship from the University of Szeged, Albert Szent-Györgyi Medical School, and won a Best Poster award in February 2024. She is a member of the America Society of Aerospace Medicine Specialists, the Space Surgery Association, the Aerospace Physiology Society, and the Aerospace Nursing and Allied Health Professionals Society.

Jeffrey R. Davis, M.D., Aerospace Medicine Endowed Scholarship

Dr. Corey Morris is a native of McMinnville, TN, United States. He received his undergraduate education at Motlow

Sate Community College and Tennessee Technological University. He worked for his local community college as an adjunct laboratory instructor and assistant director of new student services before being accepted to medical school. He completed his medical education at Lincoln Memorial University- Debusk College of Osteopathic Medicine in 2022 and started his medical residency training at Lake Cumberland Regional Hospital on July 1, 2022, where he is currently a second-year Family Medicine resident. He has a wide variety of interests, including rural primary medicine, osteopathic manipulative medicine, wound care/hyperbarics, and aviation/space medicine.

Dr. Morris has served on the AMSRO executive board for two terms while a medical student and currently serves on the AsMA Communications Committee. He is a current board member of the American Osteopathic College of Occupational and Preventive Medicine representing resident physicians. He is also a member of the Civil Aviation Medical Association, the Aerospace Human Factors Association, the American College of Hyperbaric medicine, the Undersea and Hyperbaric Medical Society, the American College of Osteopathic Family Physicians, and the American Osteopathic Association. When not at work in Kentucky, you can find him spending time with family in Tennessee, building models with Legos®, or watching action, comedy, or sci-fi movies.

Philip J. Scarpa, Jr., Aerospace Medicine Endowed Scholarship

Claudio Franc was born in the northwestern region of Romania, colloquially known as Transylvania, and immigrated to the United States with his mother when he was 5 years old. As a child, his favorite question to be asked was "what do you want to be when you grow up?" because that always gave him free reign to start talking about his favorite topic and how he has always dreamed of becoming an astronaut. From reading "On the Shoulders of Giants" by Stephen Hawking at a young age, to traveling to the Kennedy Space Center for his 10th birthday, his fascination with the field of space exploration is as boundless as the universe itself. He has travelled all over the globe and has lived in many states, but calls Louisiana his home. In 2019, he graduated with his Bachelor of Science degree in Molecular Biology from Southeastern Louisiana University, with minors in chemistry, history, and psychology. In 2021, he earned his Master of Business Administration degree from the same university before matriculating into medical school at St. George's University, where he is currently enrolled as a third-year medical student.

While being engaged in his clinical rotations in New York City, Claudio is also concurrently completing in his Master of Public Health degree at Johns Hopkins University. Upon graduation next summer, he hopes to match into a general surgery residency and enlist in the U.S. Air Force with the dream of one day serving his country as a surgeon. He also has aspirations to further his knowledge and training by completing an aerospace medicine fellowship so that he may serve as a flight surgeon, with the aim of treating and preventing a variety of diseases not only here on Earth, but also, hopefully, among the stars. He is a member of the Thieme Group, where he is a Student Ambassador, and the Advocates for Safe Air Policy and Safe Air for Everyone, where he serves as a Council intern. He is a past winner of the Welch Scholarship from Johns Hopkins University and multiple awards from both St. George's University and Southeastern Louisiana University.

Associate Fellows Announced

The following members of the Aerospace Medical Association have achieved Associate Fellow status and were approved by the Executive Committee: Jennifer Benincasa, Nicola Boyd, Lauren Church, Diego Garcia, Frederick Hauser, Roy Hoffman, Sasirajan Jeevarathinam, David Leary, Max Lee, Peter Letarte, Heather Panic, Michael Pohlen, Timothy Sprott, Michael Stephens, Tesfaye Tetemke, Alicia Tucker, and Richard Whittle.

Obituary Listing

AsMA staff only recently learned that **Dr. Jay A. Danforth, B.Sc., M.D., D.Av.Med.**, of Alberta, Edmonton, Canada, died in November 2023. He was an Emeritus member and Fellow of the Aerospace Medical Association. He graduated from the University of Alberta School of Medicine and received a Diploma of Aviation Medicine (RCP) London. He served in the Canadian Forces from 1968–1976 and later became a General Practitioner in Calgary. In 1984, he joined Civil Aviation Medicine in Canada, where he served a 2-year assignment with the International Civil Aviation Organization in Jeddah, Saudi Arabia. He then returned to Civil Aviation Medicine until he retired in 2018. His last position was working with the Adult Psychiatry Unit at the University of Alberta until he fully retired in 2021. For a full obituary, please visit https://edmontonjournal.remembering.ca/obituary/jay-danforth-1089127041.

Meetings Calendar

May 19-22, 2024; 108th American Occupational Health Conference (AOHC), Loews Royal Pacific Hotel, Orlando, FL, United States. For more info, visit https://acoem.org/American-Occupational-Health-Conference-(AOHC).

July 30-Aug. 1, 2024; 13th Annual International Space Station Research and Development Conference (ISS-RDC); Boston, MA, United States. Early registration is now open until May 24. To register or for more information, please visit https://issconference.org/.

Calls for Papers

Ongoing: International Astronautical Federation (IAF) Global Networking Forum Space Conversations Series; ONLINE, 14:00 Paris time. Visit https://www.iafastro.org/events/iaf-gnf-space-conversations-series/ for more.

Aerospace Medicine and Human Performance
INFORMATION FOR AUTHORS
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These notes are provided for the convenience of authors considering preparation of a manuscript. Definitive information appears in the **INSTRUCTIONS FOR AUTHORS** as published on the journal's web site. Submissions that do not substantially conform to those instructions will be returned without review. We conform to the International Committee of Medical Journal Editors (ICMJE) Recommendations for the Conduct, Reporting, Editing and Publication of Scholarly Work in Medical Journals.

JOURNAL MISSION AND SCOPE

Aerospace Medicine and Human Performance is published monthly by the Aerospace Medical Association. The journal publishes original articles that are subject to formal peer review as well as teaching materials for health care professionals. The editor will not ordinarily review for publication work that is under consideration or has been accepted or published by another journal except as an abstract or a brief preprint.

TYPES OF PAPERS

The five types of articles specified below should be submitted through the web site and will undergo peer review. Other submissions including **Letters to the Editor, Book Reviews,** and teaching materials should be submitted by e-mail to the Editorial Office. Letters to the Editor are limited to 500 words of discussion and/or criticism of scientific papers that have appeared in the journal within the past year. *If your manuscript does not fit the parameters layed out below, an exception may be granted. Please contact the Editoiral Office to discuss your submission.*

Research Articles present the results of experimental or descriptive studies with suitable statistical analysis of results. They should contain an Introduction, Methods, Results and Discussion with a statement of conclusions. Such manuscripts should not exceed 6000 words with approximately 25 references.

Review Articles are scholarly reviews of the literature on important subjects within the scope of the journal. Authors considering preparation of a review should contact the Editor to ascertain the suitability of the topic. Reviews generally may not exceed 6000 words with up to 150 references, but longer reviews of exceptional quality will be considered.

Case Reports and ***Case Series*** describe interesting or unusual clinical cases or aeromedical events. They should include a short Introduction to provide perspective, the Presentation of the Case, and Discussion that includes reference to pertinent literature and/or review of similar cases. Such manuscripts should not exceed 3000 words with approximately 12 references.

Short Communications and Technical Notes describe new techniques or devices or interesting findings that are not suitable for statistical analysis. They should contain the same sections as a Research Article but should not exceed 3000 words with approximately 12 references.

Commentaries are brief essays that set forth opinion or perspective on relevant topics. Such manuscripts may not exceed 1000 words with approximately 10 references without tables or figures.

We also accept ***Historical Notes,*** and ***Aerospace Medicine Clinic*** (formerly **You're the Flight Surgeon**) articles.

RULES FOR DETERMINING AUTHORSHIP

Each person designated as an author should have made substantial intellectual contributions as specified in the Instructions for Authors.

ETHICAL USE OF HUMAN SUBJECTS AND ANIMALS

The Aerospace Medical Association requires that authors adhere to specific standards for protection of human subjects and humane care and use of animals. The methods section of a manuscript must explicitly state how these standards were implemented. Details appear as specified in the Instructions for Authors.

LANGUAGE, MEASUREMENTS AND ABBREVIATIONS

The language of the journal is standard American English. Authors who are not perfectly fluent in the language should have the manuscript edited by a native speaker of English before submission. Measurements of length, weight, volume and pressure should be reported in metric units and temperatures in degrees Celsius. Abbreviations and acronyms should be used only if they improve the clarity of the document.

PREPARATION OF TABLES AND FIGURES

Tables and figures should be used strictly to advance the argument of the paper and to assess its support. Authors should plan their tables and figures to fit either one journal column (8.5 cm), 1.5 columns (12.5 cm), or the full width of the printed page (18 cm). Tables should be assigned consecutive Roman numerals in the order of their first citation in the text. Tables should not ordinarily occupy more than 20% of the space in a journal article. Figures (graphs, photographs and drawings) should be assigned consecutive Arabic numerals in the order of their first citation in the text. Line drawings of equipment are preferable to photographs. All graphics should be black & white: 1200 dpi for line art; 300 dpi for photos; 600 dpi for combination art. They must be sent electronically, preferably as high resolution TIFF or EPS files. See Documents to Download online for further instructions.

REFERENCE STYLE

The style for references is the National Library of Medicine (NLM) format, using name-sequence, i.e. alphabetical by author.

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The Corresponding Author is responsible for providing complete, accurate references so that a reader can locate the original material. References must be formatted in a modified Vancouver style, and listed alphabetically, numbered, then cited by number. An extensive set of examples of different types of references can be found on the web site under Documents to Download. If electronic references are used, they should be readily available to the reader.

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PUBLICATION PROCEDURES

Once the Editor has accepted a manuscript, the electronic source files for text and figures (TIFF or EPS preferred) are forwarded to the publisher, the Aerospace Medical Association, for conversion to printable format and final copy-editing. Correspondence related to publication should be directed to the Managing Editor at the Association Home Office: (703) 739-2240, X101; rtrigg@asma.org.

When the paper is ready for publication, the printer places on its web site a PDF file depicting the typeset manuscript. The Corresponding Author will be notified by e-mail and is responsible for correcting any errors and for responding to any "Author Queries" (Qs).

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Now in our 95th Year!

The financial resources of individual members alone cannot sustain the Association's pursuit of its broad international goals and objectives. Our 95-year history is documented by innumerable medical contributions toward flying health and safety that have become daily expectations by the world's entire flying population—commercial, military, and private aviation. Support from private and industrial sources is essential. AsMA has implemented a tiered Corporate Membership structure to better serve our corporate members. Those tiers are shown below for the following organizations, who share the Association's objectives or have benefited from its past or current activities, and have affirmed their support of the Association through Corporate Membership. As always, AsMA deeply appreciates your membership, sponsorship, and support.

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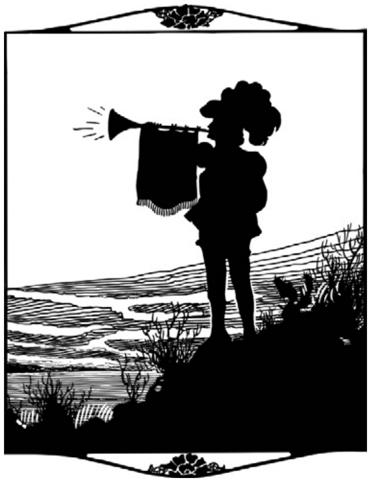
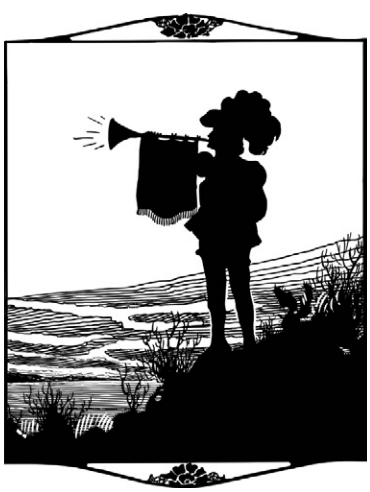
ANNOUNCEMENTS



Reminder: The meeting abstracts will be published in a proceedings issue later this summer. This decision was made for several reasons – please see either the February 2024 newsletter or p. 172 of the March 2024 issue of the Blue Journal for further details.



Additionally, plans are in process to switch the electronic journal over from Mira and Ingenta to PubFactory – all journal issues from 1930 to the present will be on that site. The new address will be available in June or July of this year. Watch AsMA's social media and newsletter for more details!

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