Asthma and Rotary-Wing Military Aircrew Selection

William D. Porter; Nicole Powell-Dunford; Grant D. Wilde; Alaistair J. R. Bushby

BACKGROUND: From a population-based perspective, reports in the peer-reviewed medical literature suggest an increase in the overall prevalence of asthma in recent decades. Applicants for military aviation training with a current or past history of asthma are generally excluded in the United Kingdom.

METHODS: In order to assess the impact of the prevalence of asthma on the available pool of military service candidates, the authors collected data on annual live births between 1916 and 2016 as well as peer-reviewed publications that provided insight into asthma prevalence trends within the United Kingdom across the last century (covering birth-year population cohorts ranging from 1924 to 1995). Regression techniques were used to estimate the prevalence of individuals who could reasonably expect to be found unfit for military aviation service due to asthma-like conditions within the birth-year cohorts between 2001 and 2016.

RESULTS: Between 1916 and 2016, the number of live births in the United Kingdom has averaged approximately 802,000 per year. The reported prevalence of asthma, based on the assimilated data points, ranged from 2.3 cases per 1000 individuals among the 1924 birth-year cohort, to 29.8 cases per 1000 individuals among the 1990 birth-year cohort.

DISCUSSION: Based on the data and analysis presented above, asthma continues to constitute a significant public health issue in the United Kingdom. Military services must base risk mitigation decisions on accurate and precise diagnostic categorizations, and prudently balance the benefits of allowing affected individuals to participate in military service with the potential for mission degradation or compromise.

KEYWORDS: asthma, military, aircrew.

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Asthma is a common affliction with significant employment implications that may resonate far forward in the lives of those individuals who receive the diagnosis at an early age. Policy-makers seeking to establish prudent military employment standards related to asthma must precisely navigate an interwoven tangle of changes in the underlying epidemiology of asthma, as well as historical variation in the diagnostic precision of the condition. Current concerns over this condition are heightened due to reports in the peer-reviewed medical literature that suggest an increase in the overall prevalence of asthma in the United Kingdom in recent decades.[4] Simpson examined primary care diagnostic data from across England over the period of 2001–2005 and reported that approximately one person in nine had been diagnosed with asthma at some point in their life.[36] More recently, Mukherjee et al. estimated the lifetime prevalence of patient-reported symptoms of asthma in the United Kingdom at 29.5% (with a 95% confidence interval of 27.7–31.3%).[27] Given a strong desire for evidence-based medical selection and retention standards for the military rotary-wing aviation service, we intend to explore the existing data related to the prevalence of asthma in the United Kingdom, and the potential impact of this epidemiology on the available pool of candidates for military service.

For asthmatic individuals seeking a career in military aviation, "the potential for sudden incapacitation with acute attacks (e.g., with a cockpit smoke situation), small airways dysfunction causing V/Q mismatching thereby magnifying hypoxia, acceleration atelectasis and lowered G tolerance, the potential for pulmonary barotrauma with acute decompression, and

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adverse effects of medications" may be incompatible with such service.[33] For military service in the United Kingdom, asthma is recognized as a disorder that encompasses a wide range of potential clinical manifestations and candidates for military service may present with all possible combinations of type, frequency, and severity of symptoms. To mitigate the aeromedical risks associated with the symptoms, complications, and exacerbations of this condition, current Ministry of Defense clinical guidelines mandate a stratified approach to determine appropriate employment limitations at the point of an individual's selection for military service. Generally speaking, candidates with positive (i.e., "Yes") responses to any of the following questions are determined to be unfit for aviation service:[26]

1) Is the candidate currently on any treatment for asthma?
2) Has the candidate had any asthmatic symptoms, including nocturnal cough or exercise-induced wheezing, in the past 5 yr or since the age of 16 yr?
3) Has the candidate used any inhaler (continuously or intermittently) for control of asthma or wheeze for a period >8 wk in the 5 yr before application?
4) Has the candidate required more than one course of oral steroids for asthma or wheeze since the age of 5 yr?
5) Has the candidate required admission to an intensive care unit for asthma at any time in their life?
6) Has the candidate required a hospital admission >24 h for asthma or wheeze since their 5th birthday?

Employment decisions are ultimately based on data gathered from this focused clinical history and supported by additional physical examination findings, objective tests of pulmonary function, and (where indicated) referral to subject-matter experts for adjudication.[26]

When present, the physiological limitations associated with asthma underpin a reasonable exclusion of afflicted individuals from serving in high-performance military aircraft. However, one must ask if the challenges of the rotary-wing flight environment necessitate the same level of risk mitigation for those with asthma? Williams et al. defined the hallmarks of the rotary-wing flight environment with "lower altitudes and airspeeds, without supplemental oxygen, and with less acceleration exposure," all of which potentially reduce the stressors on an aircrew's respiratory system that could be associated with other forms of flight.[43] Conversely, rotary-wing aircrew may experience routine exposures to pulmonary irritants, dust, and other asthmagenic particulate matter while operating in close proximity to the ground, and although military rotary wing crews typically fly at low altitudes above ground level (AGL), the operational area may be at a high altitude above mean sea level (MSL), requiring supplemental oxygen delivery systems to sustain human performance. Low flying rotary-wing aircrews may also be exposed to other battlefield chemicals that are respiratory irritants, such as chemical warfare agents, products of combustion, and infectious agents, while operating across the full range of potential conflict scenarios.[38]

METHODS

Subjects

In order to assess the impact of the prevalence of asthma on the available pool of military service candidates, estimates of annual live births between 1916 and 2016 were collected from the Office for National Statistic's vital statistics dataset population and health reference tables.[30] While planning this project, the authors were mindful of the requirements for ethical review of research outlined in Joint Services Publication 536, *Ministry of Defense Policy for Research Involving Human Participants.* This project did not involve human subjects, instead relying upon on population-based data points drawn from publicly available manuscripts. As such, it was determined to be exempt from ethical review.

Materials

The authors identified 12 publications from the readily available peer-reviewed medical literature that provided insight into asthma prevalence trends within the United Kingdom birth cohorts within the last century. An initial search of PubMed using the generic terms "asthma prevalence United Kingdom" provided 2388 initial references. Items published in languages other than English were excluded ($N = 19$), as well as references that lacked abstracts ($N = 346$). Publications limited by specific racial, gender, socio-economic, or other demographic categories were also generally excluded ($N = 156$). Abstract titles were then screened for publications that included generalized estimates of annual asthma prevalence, and which facilitated analysis based in the context of birth-year cohorts. This screening resulted in the exclusion of 1808 references. An additional 44 references were excluded due to a lack of reliable age-specific prevalence rate information. This overall process resulted in 15 peer-reviewed publications that provided asthma prevalence estimates for United Kingdom birth-year population cohorts ranging from 1924 to 1995. Upon further review, three of these references were excluded because they represented iterative publications of longitudinal data that would have been repetitive. However, the most recent reference from each of these studies was included in the model (described below). The age of each population being studied at the time of data collection demonstrated wide variability among the selected publications, ranging from 6 to 50 yr of age.

Procedure

Asthma prevalence rates were drawn from each of the selected publications and appear in **Table I**. Of note, as the hypothesis of concern for the current study was primarily related to overall asthma prevalence, individual data points from each bibliographical source provide reported percentages of individuals in which asthma had ever been diagnosed.

Statistical Analysis

Once the data was consolidated, a scatterplot was constructed in Microsoft Excel 2010 using percentages of asthma prevalence as the dependent variable (on the Y-axis), and calendar

Table I. Reported Prevalence of Asthma Among United Kingdom Birth-Year Cohorts, 1924–1994.

AUTHOR	DATA COLLECTED	POPULATION AGE	BIRTH YEAR	ASTHMA %
Upton[40]	1974	50	1924	2.3
Upton[40]	1996	50	1946	6.8
Kaplan[22]	1969	11	1958	3.5
Peckham[32]	1969	11	1958	3.5
Burr[11]	1973	12	1961	5.5
Burney[10]	1973	12	1961	1.2
Burney[10]	1973	11	1962	2.5
Burney[10]	1973	10	1963	1.8
Burney[10]	1973	9	1964	1.8
Burney[10]	1973	8	1965	2.1
Burney[10]	1973	7	1966	2.6
Burney[10]	1973	6	1967	1.5
Burr[11]	1988	12	1976	12.0
Osman[31]	1989	10	1979	8.9
Ng[29]	1991	9	1982	17.9
Anderson[5]	1995	13	1982	20.6
Shamssain[35]	1995	13	1982	22.5
Rizwan[34]	1991	8	1983	17.7
Butland[12]	1991	7	1984	7.8
Osman[31]	1994	10	1984	18.8
Rizwan[34]	1993	8	1985	22.0
Shamssain[35]	1995	7	1988	22.9
Shamssain[35]	2001	13	1988	25.7
Osman[31]	1999	10	1989	20.4
Anderson[5]	2002	13	1989	25.9
Ng[29]	1999	9	1990	29.7
Rizwan[34]	1998	8	1990	29.8
Font-Ribera[18]	1998	7	1991	20.2
Burr[11]	2003	12	1991	27.3
Osman[31]	2004	10	1994	14.8
Shamssain[35]	2001	7	1994	26.9
Butland[12]	2002	7	1995	13.8

birth-year cohort as the independent variable (on the X-axis). Regression lines were applied to the asthma prevalence data points using the LINEST function and 95% confidence intervals were calculated. As the focus of this project was the impact on asthma prevalence for aircrew selection, estimated prevalence (from the regression line) was used to predict the percentage range of individuals who could reasonably be expected to be found unfit for military aviation service due to asthma within the birth-year cohorts between 2001 and 2016.

RESULTS

Between 1916 and 2016, the number of live births in the United Kingdom has ranged from approximately 657,000 live births in 1977, to over 1.1 million live births in 1920, with an average number of live births of approximately 802,000 per year. In the most recent decade (2006–2016), the average number of live births was approximately 785,000 per year, with a maximum of 812,000 live births in 2012, and a minimum of 748,000 live births in 2006. The reported prevalence of asthma, based on the assimilated data points, ranged from 2.3 cases per 1000 individuals among the 1924 birth-year cohort to 29.8 cases per 1000 individuals among the 1990 birth-year cohort. Table I provides the observed patterns of asthma prevalence.

Fig. 1 provides a graphical representation of the combined live birth and asthma prevalence data, the resultant linear regression line, and the calculated 95% confidence intervals for the trend. The linear regression model generated an R^2 value of 0.62, suggesting that the trend line explains a generous amount of the relative variability between the dependent and independent variables, but should be interpreted with caution. Additionally, the residual sum of squares for the model was 1176.13, with an F statistic of 48.52 (given 30 degrees of freedom).

DISCUSSION

Based on the data and analysis presented above, asthma continues to pose a significant public health challenge to the United Kingdom, with the trend analysis suggesting that the problem may worsen in the future. If current military aviation service exclusion criteria remain in place (against a rising likelihood of applicants with potentially exclusionary diagnoses), the pool of talent available for military aviation service could potentially grow ever smaller over time. This could challenge the ability of the United Kingdom's Ministry of Defense to recruit, train, and retain the most qualified candidates. A potential solution to this problematic scenario could include expanded rotary-wing aviation roles for individuals with asthma or risk of asthma relapse. Any such expansion would most certainly require confidence in clinical diagnostic determinations to exclude moderate or severe forms of asthma and be followed by the applicants' ability to undertake all required military training and duties without performance limitation. Applicants' medical histories would also need to reliably lack any instances of sudden or severe exacerbations (or hospitalizations). The relative historical success of other military and civilian regulatory organizations in considering asthmatics for flight may also prompt consideration of change. Before suggesting any such change, the strengths (and weaknesses) of the analysis described above must be considered as part of the policy development process.

First, changes in diagnostic categorization over time could represent a legitimate source of bias in any analysis of the historical epidemiology of asthma. The National Institute for Health and Care Excellence (NICE) currently provides readily available and objective diagnostic criteria for diagnosing

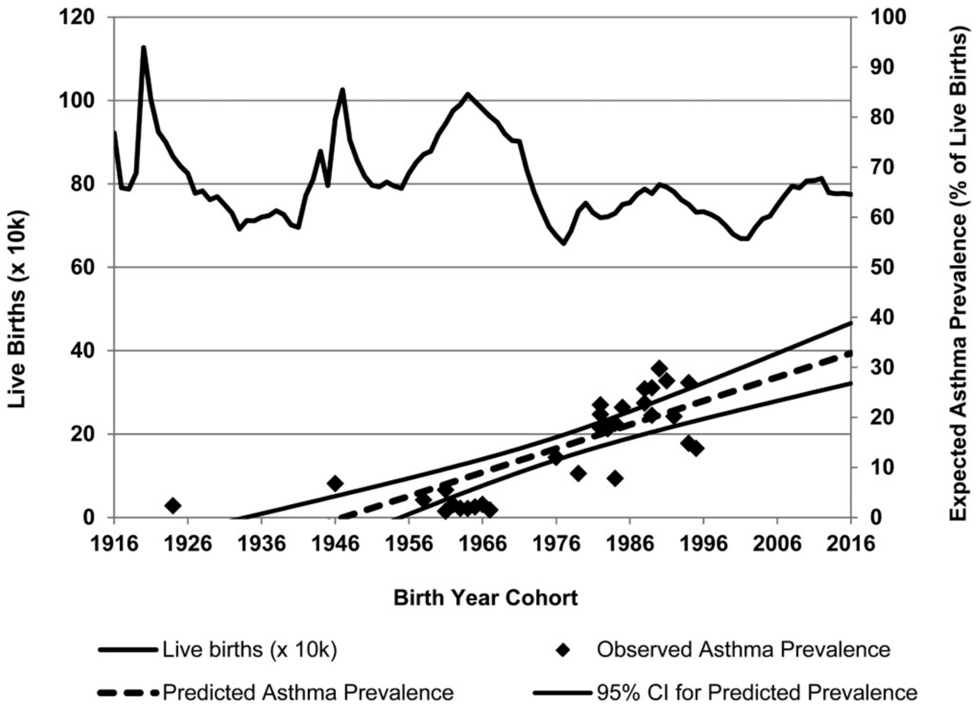

Fig. 1. Asthma prevalence as a percentage of live births (United Kingdom, 1916–2016).

asthma in adults, young people, and children ages 5 and over. Clinicians are currently encouraged to diagnose asthma in individual patients based on a structured clinical history, a focused physical examination, the use of objective tests, and confirmation that alternative diagnoses have been appropriately excluded.[28] Specifically, they endorse the measurement of fractional exhaled nitric oxide (FeNO), the use of spirometry to calculate the ratio of the forced expiratory volume in the first second of exhalation (FEV_1) to the forced vital capacity (FVC), the measurement of bronchodilator reversibility in terms of the FEV_1/FVC ratio, the 2–4 wk diurnal variation in peak expiratory flow (PEF), and the diagnostic utilization of substances that are known to invoke airway hyper-reactivity (including histamine and methacholine).[28] However, these objective criteria have evolved over time as the science related to asthma has matured. For example, the measurement of exhaled nitric oxide emerged in the early 1990s as a possible diagnostic marker of pulmonary vascular regulation and inflammation.[3,19] This historical variability in diagnostic fidelity is a potential source of bias when looking at historical asthma incidence and prevalence data across the Western world, and this effect on the predicted asthma prevalence among birth-year cohorts is difficult to quantify over time. Nevertheless, it must be considered when estimating the impact of asthma on the suitability for military service of individuals within future birth cohorts.[16,25]

Secondly, clinical practice patterns related to asthma have morphed across time in order to address potentially excessive morbidity and mortality attributed to the disease. As early as 1990, the British Thoracic Society published guidelines for the diagnosis and management of both chronic persistent asthma and acute severe asthma, emphasizing the early recognition of symptoms, optimization of treatment aimed at the restoration of lung function, and a simultaneous focus on the reduction in risk of severe attacks.[6,7] Heightened consideration for asthma may also partially explain an increased attribution of the diagnosis of asthma (with a subsequent rise in both incidence and prevalence) as clinical healthcare providers adopted more aggressive diagnostic and treatment approaches. This phenomenon was not an isolated occurrence within the United Kingdom, as similar changes in practice patterns developed in the United States, Canada, and other locations to varying degrees.[17,23,24] The effects of these fluid changes in diagnostic categorization and management must be considered when estimating the impact of asthma on the suitability for military service of individuals within future birth cohorts.

Lastly, the fact that the risk stratification approach used to determine fitness for military service is informed (to at least some degree) by prior clinical evaluations is also a source of potential bias. Aaron et al. conducted a multicenter trial that prospectively evaluated 613 randomly selected patients with a known history of physician-diagnosed asthma using "home peak flow and symptom monitoring, spirometry, and serial bronchial challenge tests, and those participants using daily asthma medications had their medications gradually tapered off over 4 study visits...Current asthma was ruled out in 203 of 613 participants…".[1] If generalizable, this trend is concerning, and should be considered when reviewing the medical history of both asthmatics and nonasthmatics alike. In their most recent clinical practice guideline, the British Thoracic Society echoes this precautionary guidance regarding the diagnosis of asthma by stating, "the absence of consistent gold-standard diagnostic criteria means that it is not possible to make unequivocal evidence-based recommendations on how to make a diagnosis of asthma…Central to all definitions is the presence of symptoms (more than one of wheeze, breathlessness, chest tightness, cough) and of variable airflow obstruction. More recent descriptions of asthma, in both children and adults, have included airway hyper-responsiveness and airway inflammation as components of the disease reflecting a developing understanding of the diverse subtypes (phenotypes and endotypes) of asthma and their underpinning mechanisms."[8] Therefore, rigorous risk-stratification approaches must be maintained in order to adequately identify service applicants who are indeed "fit to perform their Service duties" while providing fairness and impartiality throughout the selection system.[26]

Various authors have examined the potential for military mission degradation due to the effects of asthma. Dickinson conducted a retrospective review of British Army hospital admissions and military discharges from 1983–1986 where asthma was the primary diagnosis and estimated that if a notional population of "100 recruits with a history of childhood asthma were accepted into the Army under the present policy and followed up to their late twenties, assuming that none left the service for other reasons, 40 would be wheeze free, 25 would have experienced sufficient wheeze to risk downgrading and even medical discharge, and 35 would have been discharged because of serious asthma."[15] Presumably due to increasing and widespread availability of medications that help control asthma symptoms, recent authors provide perspectives that are more optimistic. Ireland et al. compared outcomes associated with a relaxed recruitment standard for asthma in the Australian Defense Force and concluded that allowing individuals with asthma to serve while taking low-dose medications did "not result in unanticipated medical or administrative costs to the organization."[21] Millikan et al. examined the impact of a policy change that allows for retention of U.S. Navy recruits diagnosed with asthma during initial military training and concluded that "64% of recruit training graduates diagnosed with mild asthma were retained on active duty without adverse consequence up to 3 years after entering active duty."[25]

In contrast to the optimistic assessments above, the link between specific deployment-related exposures and respiratory effects has been an area of intense scrutiny following recent combat operations in Southwest Asia. Smith et al. conducted a prospective population-based study with follow-up data from over 55,000 participants and concluded that "deployers had a higher rate of newly reported respiratory symptoms than non-deployers (14% vs. 10%), while similar rates of chronic bronchitis or emphysema (1% vs. 1%) and asthma (1% vs. 1%) were observed."[37] Abraham et al. used a nested case-control design to leverage military deployment manpower data and electronic medical records to conclude that "specific environmental exposures, rather than deployment in general, are determinants of post-deployment respiratory illness."[2] Lastly, Brooks warned that "there remains no absolute standard for the diagnosis of asthma in remission and no objective screening test predicting the potential risk or severity of future asthma attacks. It has not yet been substantially established whether particular environmental exposures, noted during military deployment, are associated with asthma recurrence and/or new-onset asthma cases. Medical evidence hints that recruits with a history of childhood asthma quiescent since their 13th birthday might still be at risk for asthma exacerbation or new-asthma onset following adverse environments exposure accompanying military deployment."[9] The potential impact of similar environmental hazards in future periods of conflict must remain at the forefront of any discussion of military selection and retention standards related to asthma.

Beyond general military service, Hopkirk reviewed the natural history of asthma in relation to aviation service and concluded that "asthma is incompatible with flying."[20] He perceived that the aeromedical risk exceeded any potential benefits, while noting the potential for loss of any return on the excessive investment of resources that must be devoted to pilot training. More recently Carter et al. retrospectively examined a population of 19 Israeli aviators (composed of 11 high-performance pilots, 2 high-performance weapon system operators, 3 rotary-wing pilots, and 3 transport pilots) who were diagnosed with asthma while serving in the military and found no evidence of sudden incapacitation or other incidents that would jeopardize flight safety.[13] As rotary-wing technology continues to advance, it is possible that future performance envelopes of specific platforms may blur the distinction between current rotary-wing characteristics and those of fixed-wing aircraft. In light of these advances, the aeromedical community must deliberately identify, evaluate, and attempt to mitigate risks across the human-performance realm in order to ensure safe and effective operations.

Although it is beyond the scope of this manuscript to review the safety-of-flight data of the pharmaceutical armamentarium currently available to treat (and control) mild asthma symptoms, applicable clinical practice guidelines highlight the importance of short-acting bronchodilators, inhaled corticosteroids, long-acting β_2 agonists, and leukotriene receptor agonists.[8] It is worth noting that both the Federal Aviation Administration and the Civil Aviation Administration currently permit flight operations among mild asthmatics that control their symptoms with varying combinations of these select medications.[14,42] Under current military standards issued by the U.S. Department of Defense, "History of airway hyper responsiveness, including asthma, reactive airway disease, exercise-induced bronchospasm or asthmatic bronchitis, after the 13th birthday" is considered disqualifying.[39] However, current U.S. Army aeromedical policies (primarily focused on risk mitigation in the rotary-wing environment) allow for waivers of this standard for both mild intermittent and mild persistent asthma if waiver applicants are able to demonstrate adequate performance of all required military training and duties without activity limitations, lack a history of sudden severe exacerbations or hospitalizations, and have not required recurrent treatment with oral steroids.[41] As future treatment modalities develop, their aeromedical compatibility must be continually assessed. It is even possible that curative treatments could arise, ultimately negating any impacts of the changing epidemiology of asthma on aircrew (regardless of aircraft type or role). To summarize, the availability of medication regimens that have been currently deemed safe for use in the flight environment and their associated regulatory perspectives should be considered as part of any future decisions related to asthma and military flight compatibility.

In conclusion, asthma continues to pose a significant public health challenge to the population of the United Kingdom and will continue to complicate the recruitment, training, and retention of military personnel for the foreseeable future. However, expansion of rotary-wing aviation roles for individuals with asthma may provide some relief from this tension and could be considered as an option for aeromedical policymakers.

Ultimately, the practice of aviation medicine focuses on the identification, evaluation, and mitigation of risk. In this case, do the risks from the known physiological challenges of the rotary-wing flight environment outweigh the benefits of gaining an otherwise highly qualified applicant with a diagnosis of asthma (that is potentially speculative), and who lacks any of the concerning harbingers that would suggest they would be unable to adequately perform the military duties expected of them?

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