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Review Article

Healthy Nutrition, Physical Activity, and Sleep Hygiene to Promote Cardiometabolic Health of Airline Pilots: A Narrative Review

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Background: Airline pilots experience unique occupational demands that may contribute to adverse physical and psychological health outcomes. Epidemiological reports have shown a substantial prevalence of cardiometabolic health risk factors including excessive body weight, elevated blood pressure, poor lifestyle behaviors, and psychological fatigue. Achieving health guidelines for lifestyle behavior nutrition, physical activity, and sleep are protective factors against the development of noncommunicable diseases and may mitigate the unfavorable occupational demands of airline pilots. This narrative review examines occupational characteristics for sleep, nutrition, and physical activity and outlines evidence-based strategies to inform health behavior interventions to mitigate cardiometabolic health risk factors among airline pilots.

Methods: Literature sources published between 1990 and 2022 were identified through electronic searches in PubMed, MEDLINE (via OvidSP), PsychINFO, Web of Science, and Google Scholar databases, and a review of official reports and documents from regulatory authorities pertaining to aviation medicine and public health was conducted. The literature search strategy comprised key search terms relating to airline pilots, health behaviors, and cardiometabolic health. The inclusion criteria for literature sources were peer-reviewed human studies, meta-analyses, systematic reviews, and reports or documents published by regulatory bodies.

Results: The results of the review show occupational factors influencing nutrition, sleep, and physical activity behaviors and delineate evident occupational disruptions to these lifestyle behaviors. Evidence from clinical trials demonstrates the efficacy of nutrition, sleep, and physical activity interventions for enhancing the cardiometabolic health of airline pilots.

Conclusion: This narrative review suggests that implementing evidence-based interventions focused on nutrition, physical activity, and sleep could help mitigate cardiometabolic health risk factors among airline pilots, who are particularly susceptible to adverse health outcomes due to unique occupational demands.

Keywords: Aerospace medicine, Eating behavior, Exercise, Occupational health, Preventive medicine

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INTRODUCTION

Airline pilots experience unique occupational demands which present risks to physiological and psychological health which may be mitigated through achieving health guidelines for lifestyle behaviors; nutrition, physical activity (PA), and sleep. Cardiometabolic non-communicable diseases (NCDs) such as cardiovascular disease (CVD), stroke, and diabetes mellitus are the leading cause of mortality worldwide in the general population [1]. Professional airline pilots are susceptible to similar health concerns as those occurring in the general population [2-4]. However, protective factors associated with being an airline pilot, such as favorable socioeconomic status [5], the healthy worker effect [6], and being subject to regular medical examinations [7] are thought to mitigate some health risk. Indeed, pilots have historically been considered to have a lower prevalence of NCD's and better health status than the general population [8]. Contrastingly, recent findings suggest the prevalence of cardiometabolic risk factors including body mass index > 25 (overweight or obese) and insufficient PA were higher among airline pilots globally compared with general population estimates [3].

Airline pilots experience numerous unique occupational risks related to aviation travel, such as shift work and flight schedule induced circadian disruption [9], fatigue [10], irregular meal times, mental stress demands associated with flight safety [11] and the sedentary nature of the job [12]. Consequently, these factors adversely affect physiological and psychological health and may contribute to elevated risk of long-term cardiometabolic disease and/or disability prevalence among pilots [3,13]. Furthermore, the average age of pilots is increasing, and a growing number of pilots continue to work beyond the age of 60 [14]. With greater age comes an elevated prevalence of medical conditions and complications [15].

According to the International Civil Aviation Organization's Annex 1, requirements of aviation medicine providers are to apply safety management principles to the medical assessment process, which includes evaluating data to concentrate on areas of increased risk [16]. Secondly, implementation of appropriate health promotion for license holders (pilots) to reduce future medical risks to flight safety is required [16]. The prevalence of cardiometabolic NCD risk factors are associated with shorter life expectancy [17], elevated direct health-care costs [18], reduced perceived health [19], impaired productivity [20], and higher disability-adjusted life-years [21]. With pervasiveness of NCD's internationally [1], there is a need for a paradigm shift towards more effective implementation of preventative health promotion strategies to offset these trends [13]. Behavioral countermeasures are warranted to mitigate risks of occupational morbidity, medical conditions causing loss of license, medical incapacity, and to support flight safety [22].

Nutrition, PA, and sleep are each modifiable lifestyle determinants of chronic disease [23] and influence employee work performance [24]. Habitually consuming healthy nutritional patterns, engaging in sufficient PA, and obtaining adequate sleep are three lifestyle behaviors that have a positive effect on physical health and psychological wellness [25,26], significantly lower all-cause mortality, and likely mitigate numerous NCD pathogenesis processes [27,28].

Nutrition, PA, and sleep are modifiable behaviors that are interrelated through complex bilateral interactions involving physiological and psychological mechanisms [29]. Correlational studies have observed congruent directional change effects between behaviors, in that short sleep is associated with less engagement in PA [30] and suboptimal nutrition behaviors [31]. Whereas achievement of sleep guidelines has shown associations with better diet quality [32] and may promote engagement in PA behavior. However, sufficient sleep appears to reduce barriers to, rather than predict behavior to healthy nutrition and exercise [33].

Reciprocally, some studies provide evidence for a role of diet intake [34] and exercise [35] as influencers of sleep quality. The proposed mechanisms of exercise which improve sleep include anxiolytic and antidepressant effects [36], adenosine upregulation [37], circadian phase shifting, thermoregulatory adaptations, and sleep architecture [38]. Further, chronic adaptations from exercise such as enhanced glucose metabolism, heart rate variability, and body composition may positively affect sleep [38]. A meta-analysis reported regular exercise has small beneficial effects on total sleep time and sleep efficiency, small-to-medium beneficial effects on sleep onset latency, and moderate beneficial effects on sleep quality [35]. Regular exercise may positively influence nutritional factors such as appropriate energy balance via influencing appetite regulation, total energy expenditure [39] and can promote positive psychological mechanisms related to body image, self-efficacy and mood [40].

Regular adherence to healthy nutrition patterns is associated with factors that facilitate exercise engagement and promote positive adaptations to exercise including positive cognitive and physiological performance, enhanced mood, and positive health-related quality of life [41,42]. Nutrition habits influence hormones and inflammation status, which directly or indirectly contribute to insomnia [43], and obesity promoted by chronic caloric surplus is associated with increased risk of sleep disordered breathing [44].

Health promotion interventions for pilots aimed at improving nutrition, PA, and sleep behaviors are likely to produce positive outcomes toward common perceived work-related wellbeing issues expressed by pilots, including; sleep difficulties [9], psychological fatigue [45], musculoskeletal issues [46], digestive problems [47], and may mitigate NCD risks [48]. Indeed, some evidence suggests that those who achieve health recommendations for sleep, PA and fruit and vegetable intake are more likely to achieve optimal health than those engaging in zero to one healthy behavior [49]. These observations suggest that targeting multiple behavior lifestyle-based interventions to enhance health and wellbeing may be more efficacious than single behavior interventions.

This narrative review examines (A) occupational characteristics for sleep, nutrition and physical activity, and (B) outlines evidence-based strategies to inform health behavior interventions to mitigate cardiometabolic health risk factors among airline pilots.

MATERIALS AND METHODS

1. Literature search strategy

This narrative review utilized an electronic search of bibliographic databases PubMed, MEDLINE (via OvidSP), PsychINFO, Web of Science, and Google Scholar. Eligible materials published between 1 January 1990 and 1 June 2022 were considered for inclusion, congruent with a recent review among airline pilots [3]. The literature search utilized Boolean operators AND and OR and consisted of key search terms relating to airline pilots, physical activity, nutrition, sleep, and cardiometabolic health. The reference lists of included publications were cross-checked for relevant articles. In addition, a gray literature search was performed pertaining to official reports and documents from regulatory bodies relevant to aviation and public health including the International Civil Aviation Authority, International Air Transport Association, Civil Aviation Authority, International Federation of Air Line Pilots' Associations, Federal Aviation Administration, Joint Aviation Authority, World Health Organization, and Center for Disease Control.

2. Literature inclusion criteria

The inclusion criteria for literature sources were peer-reviewed human studies, meta-analyses, systematic reviews, and reports or documents published by regulatory bodies. Only articles published in English were included in the review. The population criteria for inclusion were fixed-wing pilots (airline, commercial, civilian), and no restrictions were placed on fleet type (short-haul, long-haul, mixed-fleet).

RESULTS AND DISCUSSION

1. Sleep characteristics of airline pilots

Circadian disruption is an inherent risk for pilots and they are likely to have better sleep quality and quantity when not at work [50]. Confounding health behavior consequences that often present with circadian disruption include inadequate quality of sleep [51], altered nutrition patterns [52] and insufficient PA [53]. Sleep difficulty is frequently expressed as a primary source of work induced stress among commercial pilots [9,47]. Pilots are susceptible to a variety of regular perturbations to the natural circadian rhythm, such as shift work, extended duty periods, rotating work/rest schedules, traveling across time zones, and sleep restrictions associated with short layovers [54,55]. Sleep and wake routine consistency are a predominant challenge for both short-haul (SH) and long-haul (LH) pilots due to work schedule irregularities and shift work [9]. For LH pilots, trans meridian flight contributes to travel fatigue and circadian desynchronosis (jet lag). Travel fatigue can exhibit acute symptoms of fatigue, disorientation and headache due to sleep loss, dehydration, hypoxia, travel related discomfort and low air pressure and humidity after flying for > 8 hours [56]. Sleep debt can be substantially "made up" the next night, but jet lag lingers due to circadian misalignment with the destination time zone and the relatively slow moving internal circadian clock. Jet lag also can present symptoms including headaches, mood disturbances, daytime sleepiness, difficulty sleeping at night, poor mental and physical performance, and disrupted gastrointestinal function [57].

Within a survey of 435 commercial Portuguese pilots, the prevalence of sleep complaints was 35%, daytime sleepiness 59% and fatigue 91% [9]. Compared to office workers within the same airline, the prevalence of night waking and sleep latency were higher in pilots but did not differ significantly between LH and SH [58]. Pilots working SH often achieve less sleep on the nights before a duty period, with fatigue progressively increasing for each hour that work starts before 09:00 hours [59]. Comparatively, a study reported LH pilots achieved ≥ 7 hours sleep per night before flights, yet significantly reduced after flight duties [10]. Concerning both LH and SH pilots, another study identified > 64% of pilots achieve < 7 hours sleep per night during off duty periods [60]. Among LH pilots during off duty periods, a comparative analysis of objective and subjective sleep assessments revealed objective actigraphy measured sleep was significantly lower than self-report measures (6.8 and 7.6 hours, respectively), indicating a tendency of pilots to overestimate their sleep duration with self-report measures [61]. Furthermore, this study revealed 23% of pilots averaged < 6 hours sleep habitually [61]. Thus, consistent with reports of insufficient sleep in the general population [62], a notable proportion of pilots do not achieve sleep recommendations of 7-9 hours per night.

Insufficient sleep is highly correlated with fatigue in airline pilots [63]. Elevated fatigue is commonly reported in regional and international airline pilots [9,45], with circadian disruption, jet lag from frequent time-zone shifts, and working hour irregularities [64] known as contributing factors. Reported prevalence of perceived fatigue within commercial pilot populations range from 5% to 89% [3]. Some evidence suggests LH pilots rate fatigue higher than SH pilots [65], with night flights and jet lag presenting as chief sleep complaints in LH pilots [45], whereas prolonged duty periods, high workload, and successive early wake-ups are more prevalent complaints in SH pilots [45,59].

Fatigued pilots tend to decrease their PA, withdraw from social interactions and lose the ability to effectively divide mental resources among different tasks [54]. Furthermore, fatigue from insufficient sleep is associated with impaired immune function, increased prevalence of micro-sleeps, elevated psychosocial stress [66], and increased likelihood of elevated alcohol use [67]. Fatigue is detrimental to a pilot's ability to safely operate the aircraft or perform safety-related duties [22], and has been identified as a causal factor in numerous aviation incidents and accidents [10,55]. NASA's Aviation Safety Reporting System indicates that 21% of reported aviation incidents are fatigue related [68].

2. Promoting sleep hygiene for airline pilots

Good sleep health facilitates the ability to maintain attentive wakefulness and is characterized by duration, quality, timing, and efficiency [69]. Sleep duration guidelines proposed for adults > 18 years are seven to nine hours per night to support health and wellbeing [70]. Sleep hygiene represents a collective range of lifestyle and environmental practices congruent with supporting sleep heath, including; circadian aligned sleep schedule consistency that ensure 7-9 hours of sleep, strategic modulation of incandescent lighting and light exposure, avoidance of activities in bed other than sleep and intimacy, maintaining regular exercise and a healthy diet, sleep-disruptor avoidance in the evening (for example, caffeine or alcohol), and pre-bed routines supportive of arousal reduction and relaxation [71,72]. Furthermore, targeted sleep hygiene strategies for pilots such as preemptive adjustment of sleep schedule and prior to commencement of a new shift schedule or time zone arrival, specifically timed bright light exposure and/or light filtering eyewear, and tailored or modified nutrient timing [73,74] may support in reducing decrements in sleep quality and support jet lag recovery time [75,76]. Thus, sleep hygiene is a valuable element of health promotion for pilots, particularly within pilots of advanced age, where occupational circadian disruption may be compounded by natural age associated degradation of sleep quality and quantity [77].

Although circadian disruption is unavoidable due to occupational demands, targeted educational and behavioral interventions to improve sleep hygiene may help pilots optimize sleep behaviors around their continually changing rosters to support restorative sleep and mitigate fatigue. Guidelines suggest behavioral and cognitive interventions should be implemented whenever possible over pharmacological strategies due to their limited efficacy and side effects [78]. Common non-pharmacological approaches targeted to promote patient self-management of sleep health via educational and behavioral methods include Cognitive Behavioral Therapy for Insomnia (CBT-I), sleep hygiene, stimulus control, bedtime restriction, and relaxation improving techniques, each of which are defined elsewhere [79].

CBT-I is a multimodal approach incorporating behavioral, cognitive and educational components, which is recommended as a first line treatment for insomnia due to its moderate to strong effects on improving sleep indices [80]. However, due to the requirement of a trained practitioner and multiple treatment occasions for intervention delivery, this limits feasibility in practice, thus brief sleep interventions using components of CBT-I are more feasible. Sleep hygiene has demonstrated improvements in self-report sleep quality in blue collar employees [72] via group-based sessions, with larger positive effects observed via one-on-one delivery. While CBT-I yields significantly more effective outcomes on sleep metrics such as duration, latency and efficiency, sleep hygiene interventions as a single therapy provide small to medium effects [81]. A sleep hygiene intervention during travel and combined with light exposure following long-haul trans meridian travel has shown significant improvements in physical performance within athletes [75], however this has yet to be tested in a cognitive performance context with pilots. Sleep restriction therapy has demonstrated moderate-to-large effect sizes for reducing night waking and enhancing sleep latency and efficiency, however the impact on daytime sleepiness is inconclusive and this strategy may not be appropriate for airline pilots due to regular changes in rosters [82]. An mHealth intervention within pilots involving tailored education pertaining to sleep, PA, and nutrition health behavior elicited significant self-report improvements in fatigue, sleep quality, strenuous PA, and snacking behavior at 3 months, however the magnitude of change reduced at 6 months, yet still significant from baseline [60]. Another multicomponent intervention targeting sleep, nutrition and PA involving personalised sleep hygiene goal setting, significantly improved sleep quality and quantity, nutrition and PA behaviors, and subjective physical and mental health within pilots over four months and subsequently at 12-months follow up [50].

3. Nutrition characteristics of airline pilots

Although nutrition behaviors and knowledge of pilots are largely unexplored in the literature, unique nutritional implications are evident based on commercial aviation occupational demands. For both LH and SH pilots, irregular and long duty periods encourage inconsistent meal timing opportunities, which inhibit meal routine regularity. For LH pilots, time away from home may result in poor eating habits and increased social alcohol consumption [12,83]. Difficulty getting healthy food is a common perceived barrier within airline pilots [47], which may arise from unhealthy environmental food availability and/or lack of knowledge to make healthy eating choices. Indeed, concerns about poor nutritional content, portion sizes, and the high processed nature of food provision within airlines has been reported [84].

Eating regular well-balanced meals supports stable blood sugar regulation, whereas skipping meals increases the risk of experiencing unstable blood sugar levels. Consequently, the behavior of “quick fix” snack consumption can be triggered, which are often high in energy and low in nutrient density [85]. Chronic snacking of low nutrient density foods between main meals is associated with a higher risk of developing the metabolic syndrome and obesity [86]. Further, unstructured eating patterns may lead to inadequate intake of certain essential nutrients or over consumption of others [87].

Hormonal and metabolic functions are synchronized with the circadian rhythm [88], hence shift work can alter thermoregulation, digestion, energy metabolism, and upregulate ghrelin production which can promote positive energy balance [87]. The interaction between these physiological changes in conjunction with unhealthy food availability in the work environment facilitates lapses in nutritional control [89]. Jet lag promotes symptoms of fatigue, mood and digestive disturbances, and impaired cognitive function, all of which may affect eating decisions [74]. Associations between shift work and nutrition behaviors have been reported with alterations observed in meal patterns, skipping meals more frequently, consuming food at unconventional times, and increased consumption of saturated fats and sugar-sweetened foods [53]. Some evidence suggests a propensity for insufficient micronutrient intake (e.g. vitamin A, C and iron) and overconsumption of processed and high sodium foods such as potato chips and processed meats [90] within pilots. A comparison of daytime and shift workers within the same airline reported significantly less fruit and vegetable intake and elevated saturated fat intake in shift workers [91]. Similarly, a recent meta-analysis reported 68%-84% of pilots were not achieving fruit and vegetable guidelines [3].

The cabin environment of commercial aircraft may also influence nutrition behaviors and requirements of pilots. Altitude induced hypoxic stress affects taste and smell, and may increase palatability for sweetness [92]. Indeed, food provided on airplanes is often salty and sweet dominant [93]. Furthermore, low humidity of cabin air may accelerate dehydration [92], so an increase in fluid intake is required to counteract respiratory fluid losses.

Digestive complaints are common within commercial pilots [47]. Work related characteristics; irregular sleep, irregular meal times, large meals, inadequate fiber intake, dehydration, contaminated food ingestion and altitude pressure are associated with digestive symptoms such as epigastralgia, heartburn, bloating, constipation [58], and can be exacerbated in a high Body Mass Index (BMI) [94]. A cross-sectional comparison of digestive symptoms between pilots and office workers within the same airline found that pilots more often had bloating and poor appetite, and insomnia was the strongest predictor of digestive symptoms [58], with no significance variance in complaints between SH and LH pilots.

4. Promoting healthy nutrition for airline pilots

It is generally accepted that pilots who eat a well-balanced diet perform better, have increased energy levels, and have better physical and cognitive performance [95]. Lack of adequate nutrition through poor eating habits can be a contributing factor to fatigue, accidents or errors [96]. A healthy diet is one that provides suitable proportions of macronutrients to support physiologic and energetic requirements, maintains stable blood glucose levels, delivers appropriate energy intake without excess to support healthy body weight, while providing adequate micronutrients and hydration [97].

Numerous nutritional patterns such as the Mediterranean Diet (MED-Diet), Dietary Approaches to Stop Hypertension (DASH), Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND), Healthy Nordic Diet, Da Qing Diabetes Prevention Study, and the Finnish Diabetes Prevention Study have demonstrated NCD risk reduction in longitudinal studies in non-pilot populations [97-99]. Experimental studies with these diets have reported improvements in parameters relevant to pilot cardiometabolic health, including blood pressure, weight management, cholesterol, endothelial function, glycemic control, central adiposity, and delayed onset of CVD, type 2 diabetes, metabolic syndrome, cognitive decline and some cancers [97,100]. The composition of these diets are details elsewhere [97], however congruent principles among the diets emphasize a low glycemic load and the promotion of colorful fresh foods, including fruits and vegetables, nutrient dense whole foods, a high proportion of plant-based foods, plentiful antioxidants and polyphenols, unsaturated fats such as nuts and seeds, a high polyunsaturated to saturated fat ratio, low trans-fat, lean proteins, legumes, fiber-rich whole grains, < 1500 mg/d of sodium, omega-3 fatty acid rich foods such as fish, and avoidance of Westernized diet characteristics such as foods containing refined sugar and highly processed foods [97,101-103]. Further, mindful and slow eating is promoted in healthful diets as this facilitates awareness of internal physiological cues, sensations and emotions, nurtures parasympathetic nervous system dominance and may improve digestion [104]. Collectively, these healthy nutrition characteristics play an important role also in strengthening the immune system which enhances natural antiviral defenses and combats certain NCD pathogenic processes [105].

Structural components of these interventions include diet and exercise educational support and materials, face to face individual and/or group sessions, adherence support, counselling from a health professional, and extended care [106,107]. A review of nutrition interventions to reduce NCD risk reported frequent contact, the use of face-to-face methods, combining diet and PA interventions, and the application of behavior change techniques as components most associated with effectiveness in promoting nutrition behavior change [108]. Further, common behavior change techniques associated with positive outcomes on nutrition behavior change (for example, increasing fruit and vegetable intake) include problem identification, goal setting, self-monitoring, stimulus control, problem solving, cognitive restructuring, and relapse prevention [109].

Indeed, comparative nutrition interventions within airline pilots demonstrate efficacy for promoting cardiometabolic health. In a study within Korean airline pilots at risk of hyperlipidemia (> 220 mg/dL), a nutrition counseling intervention showed significant improvements at one year follow up for total cholesterol, BMI and High-Density Lipoprotein (HDL) [11]. The individualized nutrition prescription and educational counselling led by a dietitian involved nutritional intake evaluation, nutrition problem identification, education on nutrition therapy related to hyperlipidemia and educational print materials. Similarly, a personalized face-to-face nutrition goal setting session with a health coach and regular educational emails over a four-month period promoted significant improvements in fruit and vegetable intake, which was accompanied by improved weight and blood pressure management [50,110,111]. Further, an intervention targeting nutritional education delivery via a multicomponent MHealth app in airline pilots reported improvements in snacking behavior and decrease psychological fatigue [60].

Due to pilot's elevated exposure to ionizing radiation, nutritional antioxidants have been investigated in relation to Deoxyribo Nucleic Acid (DNA) damage and cancer risk in pilots [112]. One study reported pilot's consuming a high intake of niacin from food or a diet high in whole grains but low in red and processed meat were associated with decreased chromosome translocation, a known biomarker of DNA damage [113]. Moreover, a diet high in vitamins C and E, β-carotene, β-cryptoxanthin, and lutein-zeaxanthin may also protect against cumulative DNA damage in pilots [114]. These preliminary findings were observed in a small sample of pilots (n = 83) and further research is required to enhance generalizability. Abundant consumption of plant origin whole foods may reduce the risk of several types of cancer [115], due to the chemo-preventive effect related to the high levels of phytochemicals in this food. These phytochemicals interfere with several cellular processes involved in the progression of cancer and also with inflammatory processes that foster development of cancer [116]. Noteworthily, epidemiological studies indicate antioxidant intake via supplement form does not reduce cancer risk [117], however daily consumption of ≥ 600 g of fruit and vegetables is associated with reduced total cancer risk [118], emphasizing the relevance of consuming a diet rich in plant-based, whole food sources.

5. Physical activity characteristics of airline pilots

A recent study reported a pooled prevalence estimate of 51.5% for insufficient PA among airline pilots globally [3]. Occupational duties of an airline pilot involve extended periods of sedentary time sitting in the cockpit [12,119]. Lower levels of PA are associated with elevated levels of daytime sleepiness and fatigue in airline pilots [120,121] and the sedentary nature of the job as a pilot is a prevalent source of work related stress [47] and contributing factor to musculoskeletal complaints in airline pilots [84]. Due to inflight responsibilities and limited space available in the cockpit, opportunities to exercise mid-flight or break up sedentary bouts are not easily accessible. A lack of time and energy are the commonly expressed barriers to being active in general population adults, which may be confounded in pilots due to the elevated prevalence of shift work and fatigue [9]. Further, being 'too tired' around work and life schedule is also frequently reported, yet paradoxically many people self-report that sufficient PA decreases stress and increases energy [122].

6. Promoting physical activity for airline pilots

Sufficient PA to support general positive health, wellness and support NCD risk reduction in adults is suggested as the achievement of 150-300 minutes of moderate-to-vigorous physical activity (MVPA) per week, or 75-150 minutes of vigorous intensity, or an accumulative equivalent combination of both, with added health benefits of ≥ 300 total MVPA minutes per week [123]. Furthermore, muscle strengthening activity should be performed ≥ 2 times per week [124].

Exercise interventions positively influence weight management, prevention of musculoskeletal pain, enhances mood and the quality of sleep in patients with insomnia and sleep problems [29]. A meta-analysis reported acute bouts of aerobic exercise can significantly increases total sleep time, sleep efficiency, and slow-wave sleep and decreases sleep onset latency, wake after sleep onset, stage 1 Non-Rapid Eye Movement sleep, and Rapid Eye Movement sleep in comparison with a day without exercise [35]. In this study stronger effects were found in participants that exercised regularly, compared to those who did not. Physical activity interventions are generally effective in supporting short-term behavior change, but increases are not always maintained [125]. Thus, strategies should be incorporated into PA interventions to support adherence, such as extended care, follow up consultations or self-monitoring [122].

Numerous reviews suggest combined diet and PA interventions produce superior results than diet or PA alone [126], with a growing emergence of interventions additionally involving a sleep component [50]. Intervention strategies to enhance PA include face-to-face, group-based, internet-based, community-based, and print based [127] delivery, and may focus on informational, behavioral and social, or environmental and policy approaches [128]. A review of behavior change techniques associated with successful PA interventions identified; regular feedback, self-monitoring tools, elements of social support, variety in activities and a degree of friendly competition, as positive inclusions [127]. Counselling methods used in face-to-face sessions can be supportive of increasing stage of motivational readiness for PA and can significantly increase self-efficacy for participating in, and maintaining adequate levels of, PA [129].

Within airline pilots, an educational app-based intervention reported significant improvements in weekly moderate and strenuous activity (0.21 and 0.19 days per week, respectively) in pilots over a six-month intervention period [60]. In another study, a face-to-face personalized goal setting session with a health coach followed by weekly educational emails and a mid-intervention telephone call over a four month period promoted significant improvements in MVPA, which was accompanied by improved cardiorespiratory fitness, musculoskeletal fitness, weight and blood pressure management, and subjective health [110,111].

As individuals vary in barriers and facilitators to PA [130] and they have unique and often dynamic goals, personalization of interventions to promote PA should be considered as a cornerstone in health intervention development as it takes into consideration factors that underpin sustainable behavior change [122]. Type of PA should be determined by the individual's modality preferences for cardiovascular (such as walking, running, or cycling) and strengthening PA (for example, resistance equipment and/or bodyweight exercises), gym or non-gym-based settings, and individual-based or socially facilitated activities. Application of the frequency, intensity, time, and type principles [131] provides an effective framework for tailoring exercise prescription to support an individual's goals and level of experience and fitness. Gradual PA progression facilitated via patient self-monitoring where participants implement small progressive changes in PA at indicated intervals during an intervention (such as increase session duration; perform more repetitions; perform greater intensity; or accomplish more weekly bouts) promotes adaptation, behavior adherence, and is associated with enhanced self-efficacy and self-actualization [132].

7. Considerations for health interventions

Standard aeromedical practice lacks implementation of routine health promotion interventions targeting healthy diet, targeted sleep hygiene and PA routines. In a recent cross-sectional survey, the most prevalent coping strategies for work related stress within pilots were exercise, then sleep and relaxation, followed by diet [47]. Largely, pilots adopt their own coping mechanisms, rather than influence from employers [133].

Airlines adhere to regulatory requirements pertaining to annual medical examinations of pilots, which serve as identification of potential incapacitating health conditions and assess the pilots fitness to fly [22]. If the presence of serious physiological and/or psychological health issues are indicated, it can result in flying medical certificate suspension. Given pilots medical certificates are at stake during medicals, they are likely to underreport mental health problems and maladaptive stress coping mechanisms such as alcohol use, and are less likely to approach aeromedical examiners for help [47].

Collective improvements in sleep, nutrition and exercise behaviors are associated with reduced fatigue [60] and improved physical and mental health in commercial pilots [50] (Table 1). Preventive lifestyle interventions may promote work performance, flight safety, and positively impact pilot career longevity [134,135]. Unaddressed modifiable health risks of disease and disability can result in substantial direct and indirect costs long term [21], thus cost-effective interventions likely translate to significant economic value long term [136].

Facilitation of behavior change is a common goal of pre-

Table 1. Studies examining sleep, nutrition, and/or physical activity to enhance cardiometabolic health parameters of airline pilots

Author (Yr)	Aim of study	Design; data; country	Sample; % male; age (yrs)	Outcome measures	Key findings
Choi and Kim (2013) [11]	Evaluate the effects of physical examination and diet consultation on risk factors for cardiovascular disease.	Clinical trial; subjective and objective; Korea	n = 326; 100%; 30–39 yrs = 47%, 40–49 yrs = 33%, 50–59 yrs = 20%	Body mass index (BMI); venous blood test (total cholesterol, High-Density Lipoprotein [HDL], Low-Density Lipoprotein, Triglyceride); blood pressure.	Physical examination and intensive management with diet and exercise consultation were associated with significant improvements in total cholesterol, BMI and HDL at 12-mo follow-up.
Van Drongelen et al. (2014) [60]	Investigate the effects of an mHealth intervention to mitigate fatigue.	Clinical trial; subjective; Netherlands	n = 502; 93%; 41 ± 8 yrs	BMI (self-report); Jenkins Sleep Scale; Pittsburgh Sleep Quality Index; Short Health Form-36 Health Survey; Self-report weekly exercise sessions; Self-report snacking behavior.	The intervention improved physical activity, snacking behavior, and sleep quality at 3-mo and 6-mo after baseline. Improvements in health-related behavior were associated with reduce fatigue.
Wilson et al. (2021) [50]	Evaluate the efficacy of an intervention for enhancing nutrition, sleep and physical activity during Coronavirus disease 2019 (COVID-19).	Clinical trial; subjective; New Zealand	n = 79; 82%; 42 ± 12 yrs	Weekly physical activity (PA), sleep quality and duration, fruit and vegetable intake, and self-rated health.	The 17-wk intervention elicited significant improvements in sleep quality and quantity, fruit and vegetable intake, and moderate-to-vigorous physical activity. Improvements in sleep, fruit and vegetable intake, and physical activity were associated with enhanced physical and mental health outcomes and may support quality of life during an unprecedented global pandemic.
Wilson et al. (2021) [111]	Evaluate the 12-mo follow-up effects of an intervention for enhancing nutrition, sleep and physical activity of overweight airline pilots during COVID-19.	Clinical trial; subjective and objective; New Zealand	n = 125; 90%; 44 ± 11 yrs	weekly PA, sleep quality and duration, fruit and vegetable intake, and self-rated health.	Results provide evidence that a 17-wk healthy sleep, diet and physical activity intervention can elicit and sustain long-term improvements in body mass and blood pressure management, health behaviors, and perceived subjective health in pilots and may support quality of life during an unprecedented global pandemic.
Wilson et al. (2022) [110]	Evaluate the effectiveness of an intervention for enhancing nutrition, sleep, physical activity, and cardiometabolic health parameters in overweight airline pilots.	Clinical trial; subjective and objective; New Zealand	n = 125; 90%; 44 ± 11 yrs	Maximal oxygen consumption (VO2max), body mass, skinfolds, girths, blood pressure, resting heart rate, push-ups, plank hold, weekly PA, sleep quality and duration, fruit and vegetable intake, and self-rated health.	Findings demonstrate that a personalized 16-wk healthy eating, PA, and sleep hygiene intervention can elicit significant short-term improvements in physical and mental health outcomes among overweight airline pilots.

ventive health interventions. The prominent challenge in health behavior change interventions is poor long-term adherence, despite promising initial improvements [122]. Accountability inherent in the social interaction between a patient and a health care provider encourages completion of a specified course of action and affects motivation to adhere to treatment [137]. Within lifestyle-based health behavior interventions, extended care (for example, a 15-20 week intervention followed by monthly contact with the treatment provider for 12 months) improves adherence and intervention effects [138]. Extended care by a health care provider appears to be a strong predictor to maintaining behavioral changes in light of diminishing progress after the intervention (e.g. the lack of continued improvement in behavior when moving from improvement phase to maintenance) [139]. However, the main problem with increasing intervention duration is the corresponding cost of treatment due to the time and expertise required of health professionals to deliver care. Consequently, cost efficient methods for treatment delivery have been investigated including telephone, internet, and mobile based modes of delivery [140].

Using components of digital technology may offer solutions to traditional challenges because of their low cost, high reach capability, anonymity, adaptability, and scalability [141]. Mobile application (mHealth) and internet-based interventions have reported short term effectiveness for improving diet and PA, with reduced effectiveness over time due to diminished engagement [60,142], reinforcing the importance of extended care via face-to-face sessions or telephone calls between the health care provider and participant to support treatment effects and intervention adherence. Indeed, it has been proposed that a face-to-face component combined with an mHealth platform may be an effective approach to satisfy the evident benefits of face-to-face care [143] and to minimize cost of long-term extended care [144].

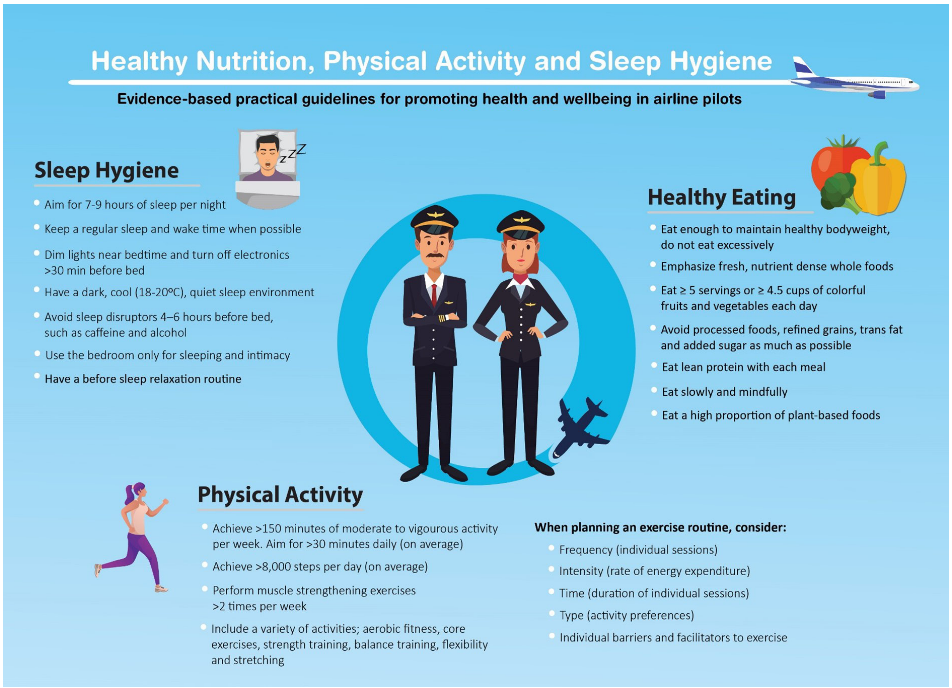
Interventions that integrate health behavior theories (detailed elsewhere [145]) into their design, particularly incorporation of multiple behavior change techniques, are more effective in improving health behavior than those that do not [146]. The social cognitive theory provides a framework that relates to a reciprocal relationship between personal factors (for example, cognitions and emotions) and aspects of the social and physical environment which influence behavior [147]. Health related knowledge, self-efficacy, self-regulation, and problem solving of barriers are four social cognitive theory constructs, which, when integrated into lifestyle interventions support health change sustainability. Health-related knowledge can be advanced by provision of educational content pertaining to the influence of sleep, healthy eating and PA on weight and risk for disease [60]. Self-efficacy beliefs and outcome expectancies are enhanced through the use of short-term, achievable goals that provide a series of successful experiences in changing eating and exercise behavior [148]. Self-regulatory skills are improved through the use of goal setting, use of self-monitoring tools, self-reinforcement, stimulus control, and cognitive restructuring strategies [147]. Finally, the ability to overcome barriers to change can be supported through extended care contact with the health care provider and direct training in problem-solving skills [122].

8. Limitations and future research

A limitation of this review was the absence of quality evaluation for individual studies. For a comprehensive systematic review and quality evaluation of literature pertaining to cardiometabolic health risk factors among airline pilots, readers are referred the recent work of Wilson and colleagues [3]. The present study suggests that single or multi-component interventions that comprise of evidence-based guidelines for sleep, healthy eating and PA may be helpful in the design of interventions to promote positive health and mitigate NCD risks in pilots. With pilots being subject to annual or biannual medical examinations, this presents an opportunity for aviation health care professionals to implement ongoing preventive health behavior interventions. Indeed, some previous research has demonstrated nutrition counseling and education interventions delivered in this manner showed significant improvements at one year follow up for total cholesterol, BMI and HDL among pilots [11].

Given the multidirectional relationship between sleep, nutrition and PA and some evidence to suggest multiple-component interventions may elicit stronger participation and adherence [49], we suggest future research examine time-efficient and scalable strategies for implementation of multicomponent sleep, healthy eating and PA interventions through well controlled and adequately powered clinical trials. Future research should incorporate objective health metrics in evaluating the effectiveness of interventions on pilot health, including blood pressure, blood lipids and glycemic control, body composition, cardiorespiratory fitness, and objective methods for evaluating sleep, nutrition and habitual PA. Further, research is needed to evaluate whether implementation of lifestyle interventions is effective for reducing health care costs of pilots longitudinally.

Currently, there is a dearth of research exploring the health behavior characteristics of airline pilots utilizing objective measurements. To better inform future targeted health behavior interventions for pilots, future research should examine nutrition behaviors via direct or indirect measures of dietary recall, such as food frequency questionnaires and 24-hour recalls on both on duty and off duty periods. The measurement of sleep patterns and habitual PA



Healthy Nutrition, Physical Activity and Sleep Hygiene

Evidence-based practical guidelines for promoting health and wellbeing in airline pilots

Sleep Hygiene

- Aim for 7-9 hours of sleep per night
- Keep a regular sleep and wake time when possible
- Dim lights near bedtime and turn off electronics >30 min before bed
- Have a dark, cool (18-20ºC), quiet sleep environment
- Avoid sleep disruptors 4–6 hours before bed, such as caffeine and alcohol
- Use the bedroom only for sleeping and intimacy
- Have a before sleep relaxation routine

Healthy Eating

- Eat enough to maintain healthy bodyweight, do not eat excessively
- Emphasize fresh, nutrient dense whole foods
- Eat ≥ 5 servings or ≥ 4.5 cups of colorful fruits and vegetables each day
- Avoid processed foods, refined grains, trans fat and added sugar as much as possible
- Eat lean protein with each meal
- Eat slowly and mindfully
- Eat a high proportion of plant-based foods

Physical Activity

- Achieve >150 minutes of moderate to vigourous activity per week. Aim for >30 minutes daily (on average)
- Achieve >8,000 steps per day (on average)
- Perform muscle strengthening exercises >2 times per week
- Include a variety of activities; aerobic fitness, core exercises, strength training, balance training, flexibility and stretching

When planning an exercise routine, consider:

- Frequency (individual sessions)
- Intensity (rate of energy expenditure)
- Time (duration of individual sessions)
- Type (activity preferences)
- Individual barriers and facilitators to exercise

Fig. 1. Evidence-based practical guidelines for promoting healthy nutrition, physical activity, and sleep hygiene to promote cardiometabolic health of airline pilots.

levels should be explored using objectives methods such as actigraphy.

CONCLUSION

Professional airline pilots are susceptible to similar health concerns as those occurring in the general population and they experience numerous unique occupational risks related to aviation travel. With the pervasiveness of NCDs worldwide, a paradigm shift is needed towards increased implementation of preventive medicine to mitigate the risk of NCD occurring in order to reduce social, financial and health system burden while maximizing pilot health, wellness and work life longevity. The attainment of evidence-based guidelines for sleep, healthy eating and PA promotes health, wellness, and mitigation of risk for long-term health conditions. Preliminary evidence of health behavior interventions in pilots suggest they promote positive effects on health behavior status, enhance subjective health and wellness, and improve cardiometabolic health. Our evidence-based practical suggestions, presented in Fig. 1, may inform health promotion intervention development for the airline pilot population regardless of age, ethnicity or sex. Aviation health and occupational safety professionals, representatives and researchers are encouraged to integrate sleep hygiene, healthy eating and PA interventions in order to pursue enhanced health care for airline pilots.

NOTES

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- **Authors' contributions:** D.W. and N.G. participated in conceptualization of the study, curated the data, conducting the formal analysis, and developed the methodology. D.W. administered the project and provided resources and software. M.D., B.J., and N.G. supervised the study and provided validation. D.W. visualized the data and wrote the original draft of the manuscript. D.W., M.D., B.J., and N.G. reviewed and edited the manuscript. All authors read and approved the final manuscript.
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