A systematic review about work-related problems incurred by agricultural pilots

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This study assesses qualitative information from primary studies on the work-related problems incurred by agricultural pilots. The aim is to shed light on what is known about these problems, which were resolved and what are the research gaps that can drive future studies to minimize accident events. In order to achieve it, a systematic review was conducted, using computerized search engines to gather primary studies on this topic, and extract qualitative information. Two different approaches were identified, those reporting data on a single work-related problem and those reporting data on existing problems in 'total work-environment', where the problems are considered as small parts of a whole. There remains a clear need for assisting these professionals, especially concerning the problems poorly addressed in the primary studies, such as organizational, informational and psychosocial factors as well as the factors that have not yet been discussed, such as education and training.

Practitioner Summary: The results of this study allow us to understand and disseminate scientific knowledge about the work situation of agricultural pilots. This knowledge allows us to fill the research gaps and promote technological and social development in this area. The benefits of such research can assist in improving the working conditions of agricultural pilots.

Keywords: agricultural aviation, work-related problems, occupational health and safety.

1. Introduction

The agricultural aviation, sometimes referred to as 'aerial application', is presented as an economic activity for dispensing any substance intended to plant nutrition, soil treatment, propagation of plant life and pest control (HRBA 137 1999; FAR PART 137 1965). Therefore, an important activity directly affects the preservation of agriculture, horticulture and forestry. Within the context of these operations are the highest rates of aviation accidents (ATSB 2011; NTSB 2011). The main causes mentioned in accident reports are collision with obstacles, power loss, engine failure, system failure, loss of control and crash landing (CENIPA 2011; ATSB 2011; NTSB 2011), but these events do not explain the root causes.

The accident reports have shown the relationship between some dangerous situations and accidents event. However, they do not address other Work-Related Problems (WRP), shown in studies from industry, civil and military aviation. To name a few, vibration (Aydog et al. 2004; Balasubramanian et al. 2011; Kåsin et al. 2011) and noise (Küpper et al. 2010; Fitzpatrick 1988; Kuronen et al. 2004), presented as contributing factors to health problems (e.g. noise can lead to hearing loss and vibration can lead to spine disorders) and safety problems (e.g. noise and vibration can decrease the pilot's performance facilitating accident events). These WRP are more evident in specific work situations and therefore require more knowledge about the work environment in agricultural aviation, in order to relate them to the accident events.

Thus, the main research question of this study is 'can the environmental conditions and the WRP incurred by the agricultural pilots make these accident events easier?' The research question raises a problem (Are there WRP or bad environmental conditions?) and an effect (Can accident events be made easier through this exposure?) to a specific professional (Agricultural pilot exposure). To answer these questions, this study draws upon qualitative information of primary studies addressing Occupational Health and Safety (OHS) in agricultural aviation, checking for approaches to exposure factors, work-related, medical or environmental problems.

2. Methods

This study was conducted through a systematic review to identify, select and include primary studies according to predefined criteria. Literature were searched in August 2011 using all databases on PubMed, ScienceDirect and Web of Science, retrospectively from 2011, according to the following search procedures. In ScienceDirect and Web of Science, was used following search algorithm ((aviat* AND agricult*) OR ("aerial application")) and it is applied through fields that include title, abstract and keywords. In PubMed, MESH Terms were used in advanced search builder to find all results on aviation (defined as aviation[MESH Terms]) and agriculture (defined as agriculture[MESH Terms]) as keywords. The search algorithm is defined as (agriculture[MESH Terms] AND agriculture[MESH Terms]). The designed algorithms try to include all studies indexed on agricultural aviation as a topic. Initially, it resulted in a large number of papers about the research question presented in section 1. In the end of the search procedures, we excluded duplicated papers.

To include only relevant data about the research topic, exclusion criteria were applied trough title and abstract of the resulting papers. They were selected by language (including only studies written in English), and by type (excluding all editorial materials, books, book chapters and grey literature). Then, we performed an assessment of eligibility, manually and standardized by two researchers independently. This step was performed by reading the title, keywords and abstract of resulting papers. Only studies showing results on agricultural aviation (including synonyms as aerial application, crop dusting, aerial spraying and external load operations) and WRP (including synonyms as exposure factor, medical or environmental problems) of agricultural pilots (including synonyms as aerial spray pilots, crop dusting pilots and external load operation pilots) were included. Reference lists of the studies retrieved were carefully screened in order to locate additional papers, not included through search procedures. Additional papers were also submitted to the same eligibility criteria applied to resulting papers.

The resulting papers were analyzed and qualitative data was extracted. Two researchers performed this step independently, and disagreements were resolved by consensus. The WRP were presented according to the following categorization: 1) organizational factors, including objectification, responsibilities, autonomy and participation of the agricultural pilots; 2) accident insurance factors, including track and flight conditions, aircraft and devices maintenance, routines failures, lack of Personal Protective Equipment (PPE) and Collective Protective Equipment (CPE); 3) natural factors, including unfavorable weather conditions; 4) environmental factors, including noise, vibration, heat, cold and 'G' forces exposure; 5) chemical factors, including particles, aerosols and toxic elements exposure; 6) operational factors, including workload, repetition, monotony, pressure for production; 7) informational factors, including detection, discrimination and identification of the information on instruments and dials; 8) communicational factors, including lack of communication devices, noises in the transmission or reception of audio or gestural information; 9) psychosocial factors, including conflicts between individuals or social groups, difficulty of communication and interpersonal interaction, lack of choice for rest, food, and leisure in the workplace; 10) drive factors, including biomechanical constraints and sizing of the workplace.

3. Results and discussion

Search procedures resulted in 911papers (93 in ScienceDirect, 604 in Web of Science and 214 in PubMed), 95 were discarded by exclusion criteria (25 by language and 70 by type), 775 were discarded by eligibility criteria (all inconsistent with the context), 13 duplicates were excluded, and finally 12 were included by additional inclusion.

Through all retrieved studies, two approaches were identified: those reporting data on a single WRP and those reporting data on the 'total work-environment', where all contributing factors are presented 'as a whole'. The synthesis of data from studies evaluating the work environment as a whole presents the workplace characteristics and their problems incurred by agricultural pilots that should be considered in studies about OHS in agricultural aviation (table 1). The exposure factors presented jointly can generate solutions to the workplace, where the mitigation of OHS problems can reduce the physical and mental fatigue, generated by the sum of hazards present in the workplace. The synthesis of data from studies evaluating a single exposure factor presents data evaluated in depth, what allows us to understand the relationship between exposure and effects on OHS (table 2). These studies are important because they highlight the hazards induced by the exposure to the work-related problem. In addition, some studies show other WRP that can increase exposure, also called contributing factors. The WRP studied on their own can generate point solutions to reduce OHS effects on agricultural pilots.

Table 1. Data from studies dedicated to the description of the entire work environment, linking multiple exposure factors.

Reference	Context	WRP inferred
Hall (1991)	Analyses activities and attitudes that occur before the accident.	ACI; ORG; PSC.
Gordon & Hirsch (1986)	Shows that the introduction of new pesticides requires a more developed and appropriate medical monitoring.	OPR; ACI; ENV; CHE.
Richter et al. (1981)	Presents a program for the prevention of deaths and injuries from aircraft accidents, according to an array of options for interventions derived from the epidemiology of road accidents.	CHE; ENV; OPR; ACI.
Quantick (1979)	Presents improvements implemented for an aircraft conception for the use in agricultural aviation operations.	ACI; INF; DRV.
Barach et al. (1970)	Investigates the factors that are likely to cause fatigue, reduce alert among pilots, and thus contribute to the increased number of accidents.	CHE; OPR; NAT; ACI; ENV.
Ryan & Dougherty (1969)	Analysis of accidents of aircraft involved in aerial application, based on accident reports.	Aircraft Type; Pilot's experience.
Perry (1969)	Description of a program for training and supervision, considering the contributing factors in accidents.	ACI; OPR; ORG.
Reich & Berner (1968)	Analysis of similarities, patterns and trends in agricultural aviation accidents.	ACI; ORG; QA.
Billings (1963)	Attempting to demonstrate clinical problems of health and environment checked in agricultural aviation.	ACI; COM; ENV; INF; NAT; OPR; ORG; PSC; CHE.
North & Hightower (1957)	Presentation of the profile of the pilots involved in four accidents with agricultural aircrafts, possible causes and solutions.	ACI; ORG.

Label: ACI=Accident insurance; COM=Communicational; ENV=Environmental; INF=Informational; NAT=Natural; OPR=Operational; ORG=Organizational; PSC=Psychosocial; CHE=Chemical; DRV=Drive.

Table 2. Data from studies that analysed a specific exposure factor.

Main WRP	Reference	Description	Contributing factors
ACI	Bruggink et al. (1964) De Haven (1953)	Lack of PPE (Bruggink et al. 1964); Lack of CPE (Bruggink et al. 1964; De Haven 1953).	Aircraft design (De Haven 1953);
ENV	Gribetz et al. (1980) Tobias (1968)	Thermal conditions (Gribetz et al. 1980); Noise (Tobias 1968).	Lack of CPE (Gribetz et al. 1980; Tobias 1968); Incorrect use of PPE (Tobias 1968); Pilot’s fluid intake management (Gribetz et al. 1980).
CHE	Chaturvedi (2011) Minasi et al. (2011) Gerry et al. (2005) Rice et al. (2005) Cable & Doherty (1999) Driskell et al. (1991) Gordon & Richter (1991) Knopp & Glass (1991) Yoshida, Antal, et al.	Exposure to chemicals (Rice et al. 2005; Smith 1963; Knarr et al. 1985; Ullmann et al. 1979; Chester & Ward 1984; Gupta et al. 1980; Cohen et al. 1979; Wood et al. 1971; Minasi et al. 2011; Gerry et al. 2005; Cable & Doherty	

CHE	(1990) Chester et al. (1987) Dellinger & Taylor (1985) Knarr et al. (1985) Chester & Ward (1984) Roan et al. (1984) Atallah et al. (1982) Quantick & Perry (1981) Gupta et al. (1980) Richter et al. (1980) Ullmann et al. (1979) Cohen et al. (1979) Simpson (1973) Wood et al. (1971) Smith (1963) Daugherty et al. (1962)	1999; Gordon & Richter 1991; Knopp & Glass 1991; Chester et al. 1987; Roan et al. 1984; Daugherty et al. 1962; Quantick & Perry 1981; Driskell et al. 1991; Richter et al. 1980; Yoshida, Antal, et al. 1990; Chaturvedi 2011; Atallah et al. 1982); Exposure to combustion gases from aircraft (Chaturvedi 2011).	
ORG	de Voogt et al. (2009) Mohler (1980)	Crew management (de Voogt et al. 2009); Health management (Mohler 1980).	Presentation of information (de Voogt et al. 2009); Communication between pilots and ground crew (de Voogt et al. 2009); Responsibilities centred on pilot (de Voogt et al. 2009); Ground crew qualification (de Voogt et al. 2009).

Label: ACI=Accident insurance; ENV=Environmental; ORG=Organizational; CHE=Chemical.

3.1. Qualitative data about exposure factors

This section presents main results on the WRP that remain harmful for the agricultural pilots.

For organizational, operational and psychosocial factors, many of the effects are similar and often contributors to accidents. The exposure to this set of factors, as for example time pressure (Hall 1991), attitude and responsibility (Hall 1991), work rhythm (Cantor & Silberman 1999; Hall 1991; Gordon & Hirsch 1986), work conditions (Yoshida, Fuzesi, et al. 1990), distance from the family (Hall 1991) and others, have psychological effects that can cause performance loss (Hall 1991) and fatigue (Gordon & Hirsch 1986). These effects can prejudice decision making, which is important for the safety of operations. Organizational factors were presented as part of the problems present in the workplace of agricultural pilots (Billings 1963; Reich & Berner 1968; Hall 1991; de Voogt et al. 2009), or related to the exposure to environmental factors (Gribetz et al. 1980) and chemical factors (Chester et al. 1987; Quantick & Perry 1981; Cable & Doherty 1999), mainly due to incorrectly performed procedures. The organizational factors presented mainly with regard to the responsibilities imposed on the pilots, either during the execution of the application itself or during related activities. During application, the pilot must conduct the initially loaded aircraft and decide the approach to each field, taking into account prevailing winds and the location of adjacent crops that could be damaged by their chemicals (Billings 1963). All this is done through commands performed with both hands and feet, with control performed through air speed, altitude and direction displays. At the end of every application, the pilot must land the aircraft near the field, generally on improvised tracks, where the plane is unloaded. Some studies presented ground crew who assist the agricultural pilot in refueling and cargo aircraft. However, in some studies, the pilots perform these procedures, even though they require a different professional qualification. Theoretically, when there is a ground crew, the pilot does not come into direct contact with products and equipment, waiting inside the aircraft cockpit. In some studies, part of the responsibility for positioning are given to ground crew, made by a professional also called flagman, who was replaced by the Differential Global Positioning Systems (DGPS). Despite the support of the ground crew, the pilot should be the responsible for managing the operation throughout the work, including the responsibility for these support professionals (Billings 1963). Regarding other activities, indirectly related to the application, we can mention the decision-making processes about aerial application, usually done with the presence of an agronomist and farmer. The agricultural pilot work requires high qualification (de Voogt et al. 2009), considering all responsibilities already mentioned, mentioned and, in cases when these professionals work autonomously, also acting as seller of their own services and management company. (Billings 1963). Operational factors are presented in the context of most studies on exposure factors in agricultural aviation. The pressure for deadlines is considered a problem to OHS of agricultural pilots since the 60's (Billings 1963), such as reducing unproductive time, loading the aircraft and maneuvering. The work rhythm is defined by the seasonality of operations, and in some periods the agricultural pilot might work for longer periods than the recommended limit (Billings 1963). The pressure for deadlines, work rhythm and competition between aerial application companies create a resistance to shift change, regardless any regulations that may be imposed (Billings 1963). In this way, higher is the work time, higher is the exposure to another factors. Psychosocial factors were presented as a part of the problems present in the workplace of agricultural pilots in only two of the studies included in this review (Billings 1963; Hall 1991). These factors do not appear as contributors in any study devoted to other factors, neither in the context of the same. As a greater concern, we can mention the distance from the family, which has psychological effects that can cause performance loss (Hall 1991), thus affecting the safety of operations.

From the studies presented in this review, most of the ones addressing natural and accident insurance factors presented them as directly related to work organization, particularly with regard to the relationship between working conditions and the procedures performed by the agricultural pilot. These factors were considered together because they are treated as complementary by literature, usually as hazards associated with occupational accidents. Natural factors were presented as part of the problems present in the workplace of agricultural pilots (Billings 1963; Barach et al. 1970). Dangerous situations include flight in unfavorable wind conditions, which compromises the safety of the pilot in the maneuvers, and the extra attention on product drift (Billings 1963). These conditions can be hazardous, especially when enhanced by other contributive factors such as noise (Tobias 1968) and fatigue, that can impair the attention. In addition, pressure for deadlines can affect the decision of a pilot on whether to work or not (Hall 1991), as an example during unfavorable wind conditions (Billings 1963). Accident insurance factors have been addressed since the first studies, back in the 60s (Billings 1963; Reich & Berner 1968; Ryan & Dougherty 1969; Barach et al. 1970; Richter et al. 1980; Gordon & Hirsch 1986; Hall 1991; de Voogt et al. 2009). Dangerous situations include lack of PPE and CPE, incorrect use of PPE and CPE, poor track conditions and obstacles in the aircraft path. Lack of use (or inappropriate use) of PPE and CPE can contribute to increase exposure to the chemicals applied (Minasi et al. 2011; Gerry et al. 2005; Richter et al. 1980; Gordon & Richter 1991) and to environmental noise (Tobias 1968). The inefficiency of PPE and CPE can also be associated with durability and lack of inspection (Billings 1963; Tobias 1968). Other accident insurance factors appear throughout all history of agricultural aviation, such as takeoff and landing on often improvised runways (Hall 1991) and low altitude flight, with the ever present danger of unexpected obstacles (Hall 1991; Billings 1963; Cantor & Silberman 1999; Barach et al. 1970).

Chemical factors were also presented as part of the problems present in the workplace of agricultural pilots (Richter et al. 1981; Billings 1963; Reich & Berner 1968; Barach et al. 1970; Gordon & Hirsch 1986). Several authors conducted studies to understand the relationships between these factors and safety (Roan et al. 1984; Minasi et al. 2011; Gerry et al. 2005; Cable & Doherty 1999; Gordon & Richter 1991; Knopp & Glass 1991; Chester et al. 1987; Daugherty et al. 1962; Quantick & Perry 1981; Driskell et al. 1991; Richter et al. 1980). There is evidence that exposure to toxic chemicals can have a contributory or causal role in agricultural aviation accidents (Reich & Berner 1968). This exposure can cause the contamination of the pilot, which can be dermal (Richter et al. 1980; Atallah et al. 1982; Chester et al. 1987; Yoshida, Fuzesi, et al. 1990), respiratory (Atallah et al. 1982), or by ingestion (Driskell et al. 1991). The contamination can be increased due to conditions of work organization or maneuvers round trip, made in some situations to reduce unproductive time (Billings 1963). So, in return, the pilot is exposed to the particles in the air, once those particles did not have enough time to deposit on the target. The dermal exposure can occur when there are failures in isolating the cockpit with the exterior of the aircraft, allowing the entry of particles and contact with the skin of agricultural pilot (Richter et al. 1980). This condition is also complicated with the absence of use of appropriate clothing (Yoshida, Fuzesi, et al. 1990) and unfavorable thermal conditions (Færevik & Reinertsen 2010) when sweat increases the skin absorption. Contamination by ingestion can occurs in crash situations, when colliding with obstacles, usually at low speeds, does not allow the dumping of chemical (Quantick & Perry 1981), and this comes into direct contact with the agricultural pilot (Testud & Bougon 2009; Cable & Doherty 1999; Driskell et al. 1991; Quantick & Perry 1981). These compounds, absorbed in any way, affect the neurological performance required to fly (Dellinger & Taylor 1985; Quantick & Perry 1981; Reich & Berner 1968; Richter et al. 1981). Newer technologies such as ULV formulation of chemicals appear to solve many of contamination problems (Gerry et al. 2005; Yoshida, Antal, et al. 1990). This is because ULV compounds do not require dilution in the field, which means less contact with the chemical. In addition, since it is a highly concentrated product, it requires special equipment with greater process control. Environmental factors were presented only as a part of the problems present in the workplace of agricultural pilots (Billings 1963; Barach et al. 1970; Gordon & Hirsch 1986; Richter et al. 1981). Among the main factors, there are noise, thermal conditions, shocks and vibrations. All these factors can significantly increase pilot fatigue (Billings 1963), leading to conditions of discomfort and reduced performance that may, in the short term, reduce safety, and in the long term affect health. The exposure to noise at high intensities and for a long period of time can cause Noise Induced Hearing Loss (NIHL) (Tobias 1968), which in turn may compromise attention and perception of warning signs. The cockpit temperature can impair physiological conditions, causing loss of body mass, dehydration, alteration of blood pressure and change in core temperature (Gribetz et al. 1980). Furthermore, in more severe cases, exposure to heat can cause loss of vigilance, which may increase the risk of pilot error (Færevik & Reinertsen 2010). Vibrations, as well as shocks and gravitational forces, are cited in some studies of agricultural aviation (Gribetz et al. 1980; Richter et al. 1980), while deeper knowledge about them was not seen in any studies presented in this review.

Informational and communicational factors were presented only as part of the problems present in the workplace of agricultural pilots in two of the studies included in this review (Billings 1963; de Voogt et al. 2009). In the 60s, experienced agricultural pilots argued that no tools could help an agricultural pilot if he was not intimately familiar with all aspects and performance limitation of his aircraft (Billings 1963). For example, existing instruments that inform the airspeed are relatively unsatisfactory, since the pilot rarely observes it during maneuvers. This is due to the demands of attention that prevail regarding maneuvers related to the field, according to the continuation of their flight plan. Nowadays, the communication conditions seem to have been partially resolved, the main concern seems to be providing resources to maintain visual lookout, adding responsibilities to the ground crew (de Voogt et al. 2009). In the main conclusions about communication between pilot and ground crew, the number of accidents could be further reduced with a suitable fuel management where the pilot and the ground crew could contribute to each other (de Voogt et al. 2009). In addition, incorporating distance communication equipment and better personal equipment are presented as possible solutions, once they make tasks easier and thus help to relieve fatigue (Billings 1963).

3.2. Workplace solutions and restrictions

Recommendations for improvement of working conditions of agricultural pilots presented in this review include: insulated cabins with air conditioning and filters; providing plenty of liquids (Richter et al. 1980; Gribetz et al. 1980); management of maximum daily working time (Richter et al. 1980); removing obstacles, and when that is not possible, performing a clear signage (Richter et al. 1980); assigning to the ground crew certain responsibilities regarding the management of obstacles, loading and refueling (de Voogt et al. 2009); periodic examinations for agricultural pilots to prevent fatigue so early (Gordon & Hirsch 1986); and appropriate professional training for both agricultural pilots and ground crew (Billings 1963).

The isolation of the cockpit, as well as the use of air conditioning, can prevent the entry of chemicals (Sawinsky & Pasztor 1977; Richter et al. 1980), controlling the thermal conditions (Gribetz et al. 1980) and reducing environmental noise. If this type of intervention can create ideal situations, with exposure below the standardized limits, then these factors do not increased fatigue. In addition, the reduction of noise exposure can enable the pilot to use sound information independently of visual attention (Billings 1963).

The assignment of responsibilities for the ground crew must be accompanied by adequate instruction, as well as for the agricultural pilots. Actions to manage daily flight hours require greater scientific knowledge in order to compare different situations and quantify the dangers existing in each one.

Despite various recommendations, it is still necessary to consider that exposure supported by agricultural pilots is a sum of all the problems present in the workplace (Parsons 2000). Therefore, the relationships between different exposures factors (figure 2) must be understood.

4. Conclusion

This study assessed qualitative information from primary studies on the work-related problems incurred by agricultural pilots. Despite a widespread search, and adding old studies, several research gaps have been identified. There is a latent need for new studies dedicated to understand current working conditions, and their restrictions. New studies can be targeted to understand the effects of exposure to specific factors (such as whole-body vibration, noise, etc.), as well as the fatigue generated by the joint exposure to all these work-related problems (The total environment).

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