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FORUM

**GENDER DIFFERENCES IN AN AVIATION
PHYSIOLOGY ENVIRONMENT**

Cass D. Howell

Men still dominate flying by better than a ten to one ratio, but there is no question that female participation in all aspects of aviation has increased dramatically in the past decade, and will no doubt continue to do so in the future. Although women have been flying airplanes since 1910, little attention was paid to them in terms of suitability and adaptability to flight, as compared to their male counterparts, until recently. It wasn't until the 1980's, after Congress modified existing law to allow women into the flight programs of the military in large numbers, that studies to ascertain what accommodations, if any, would have to be made to cockpits, training, health care, flight clothing, and a multitude of other situations hitherto largely unconsidered. Further emphasis was added as U.S. air carriers, in response to the booming expansion of the airlines in the 1990's, began hiring women pilots in unprecedented numbers.

With this greatly expanded experience base, there is sufficient data to compare differences between men and women as they relate to a flight environment.

Genetic-based impairments. This category includes deficiencies more likely to afflict one gender than the other. Although there are obviously some diseases which are the exclusive domain of a particular sex (prostate or ovarian cancers, for example) we are more concerned here with illnesses and impairments related to a flight environment.

Color blindness, if severe enough, is disqualifying for flight due to the fact that the aviation environment requires accurate color discrimination in virtually every phase. For example, airport beacons, aircraft navigation lights, Aldis lamps, VASI lights, glass cockpit displays (such as navigation and color radar), map markings, taxi and runway lights, etc., all require interpretation based on the colors presented. Unfortunately for men, color blindness is almost exclusively a male domain, and is almost always in the red and green spectrums, two colors critical in the execution of flight duties. In the American population, 8.5% of the male population inherits this condition, versus only .5% of females (Tredici, 1996). Non-genetic color blindness, i.e., acquired due to lead, drug or alcohol poisoning, multiple sclerosis or brain injury, afflict men and women equally. In milder forms, the FAA will grant waivers permitting issuance of a medical certificate, but many men are thwarted in their flying aspirations by this simple impediment.

Presbycusis. Hearing loss due to age-based

deterioration of middle and/or inner ear is called *presbycusis*, and eventually affects virtually everyone, if they live long enough. Unfortunately, again, men are disproportionately affected, acquiring *presbycusis* related losses as early as their 30's. Not only are men afflicted earlier, but they tend to suffer losses to a greater degree as well (von Gierke and Nixon, 1996). On the good side, most of the early losses are in the upper (non-conversational) frequency ranges, so *presbycusis* onset is not necessarily immediately a cause for grounding. Given that hearing directly affects a pilot's ability to communicate in and out of the cockpit, however, any hearing loss is of concern to a pilot, especially one who flies professionally. Hearing losses due to environmental (noise) causes affect men and women equally.

Decompression Sickness. Although primarily thought of as a diver's disease, DCS (the "bends") can strike aviators as well, especially those who operate at higher altitudes in unpressurized aircraft. In fact, by 1959 over 17,000 cases of aviation DCS had been documented, 17 of which resulted in fatalities (Heimbach and Sheffield, 1996). With the advent of recompression chamber therapy in recent times, deaths have been virtually eliminated, although decompression sickness itself is still occurring. Several studies have documented that females are much more susceptible to this disease, on the order of about four times more likely than men to be stricken with symptoms following low-pressure exposure. Interestingly, an 11 year review by the USAF School of Aerospace Medicine found that almost all of the increased susceptibility was associated

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with the onset of the menstrual period. For example, women within zero to four days of menstrual onset were more than five times more likely to acquire DCS symptoms than women who were twenty-five days or more from onset (Rudge, 1990). The mechanism that results in this relationship is not known. Once symptoms are acquired, women tend to be less responsive to treatment than men.

Cardiovascular Disease. Although numbers for the male-female pilot population regarding cardiovascular disease have not been determined, it is reasonable to assume they resemble the American population as a whole. As many women as men die of heart attacks in the U.S., however men are far more likely to be stricken at earlier ages, often in their forties and fifties. Women, on the other hand, are not as vulnerable until, on average, about twenty to twenty-five years later. This puts the male population more at risk during their active flying careers, with the incidence roughly doubling every decade beginning when men reach their thirties (Masters and Kohn, 1996). The good news is that cardiovascular disease has declined overall in the U.S. during the last two decades, due to changes in diet, lifestyles and medical treatment.

Cockpit Design. Scientific anthropometric considerations in aviation have been underway since before World War II, and include not only cockpit design, but also flight clothing, life support and survival equipment, and maintenance considerations. By the 1950's the U.S. Air Force had derived a large data base on the physical size of American men by measuring all pilot applicants. As a matter of practicality, the decision was made to exclude from aviation those who fell outside the 5th and 95th percentiles, i.e., were too small or too large to be accommodated in a typical military cockpit (Alkov, 1997). These size data were formalized into "military specifications" (milspecs), which were provided to aircraft design engineers so they could build cockpits that had the proper distances from flight controls, instruments, seat height, vision angles, etc. Since many civilian aircraft also have a military version, eventually these specifications found their way into practically all commercially produced aircraft made in the United States in the last 40 years.

One of the unconsidered consequences of excluding the under 5th percentile (too small) was to vastly disadvantage the female population. Seventy-seven percent of the female population falls below the male 5th percentile in sitting height, and 27% fall below in buttocks to knee length (Alkov, 1997). Reach and vision are important, but some military applications bear even more consideration. For example, the Martin-Baker ejection seat, is a widely used "zero-zero" (can be successfully used even with no altitude or airspeed to help) emergency escape device that was built

around the population data described above. At the upper end, 247 pounds is the "max boarding weight"—above that weight the seat may not clear the tail of the aircraft, with invariably fatal results. Conversely, at the lower end of the spectrum, light weight people where women predominate, run an increased risk of spinal compression and fracture, due to the more rapid onset of acceleration (Randall and Brinkley, 1996).

While some accommodations for cockpit size can be made in the form of seat cushions and "booster shoes," women do have some obstacles to overcome in this area. Current and future aircraft designs take into account a wider range of anthropometric data, so this problem will eventually resolve itself, including "smart" ejection seats that will sense the weight of the occupant and alter the rocket motor thrust accordingly. Lastly, women (and men, too) have been growing since the 1950's, and are on average 2.5 cm taller than their predecessors in the 1950's.

Strength. In addition to size differences there are significant differences in strength between men and women. Men average 40 pounds heavier in weight, and 5 inches taller in height than women, and have a better muscle-to-fat ratio. As a consequence, women are at a substantial disadvantage versus men regarding cockpit control movements (see chart) with women typically possessing about 60% of average male strength overall (Rayman, 1996). In routine operations, this disparity is not of great consequence, however it does come into play in emergency situations, where strength requirements may be vastly elevated. Pulling out of a loss-of-control dive, dealing with rudder forces in an engine-out scenario, and flying with flight controls degraded by lost hydraulic systems are examples of situations requiring either intense short-term strength application, or a prolonged endurance-type struggle. It should be noted that the results portrayed in the chart depict females in their twenties, and thus presumably at their greatest fitness level. Strength and fitness typically decline with age, therefore the capabilities in this area would be expected to decline also. (Men, of course, would experience strength loss as well, however the consequences would not be as profound, since they are starting at a higher base level.) Women have a limited ability to gain muscle mass due to hormonal influences, but strength conditioning is clearly in order. To some extent, strength issues will be mitigated by the advent of fly-by-wire technology on a wider scale basis.

Refractive Eye Surgery. Radial Keratotomy (RK), Photorefractive Keratectomy (PRK), and now, almost exclusively, Laser-assisted in situ Keratomileusis (LASIK) are increasingly common for the treatment of myopia in the United States, growing by over 100% from 1996 to 1997.

Currently, approximately one million procedures are performed each year, making refractive eye surgery one of the most popular elective surgeries available today. Although not yet approved for military aviators, refractive eye surgery is authorized by the FAA for civilian pilots, as long as certain requirements are met. In the year 2000 about 4000 male and female aviators with Class I, II, and III medical certificates who had the surgery had their surgical outcomes evaluated in a FAA sponsored study. The results indicated that female pilots were 30% more likely to have refractive surgery. More importantly, women pilots were not as likely as men pilots to have the most favorable outcomes, even when both groups were matched for initially comparable refractive error. Problems included significantly greater lack of acuity, corneal haze, glare tendencies, and myopic instability. These differences were associated with contraceptive use, pregnancy, and menopause. Although very long-term data are not yet available due to the newness of the surgeries, the FAA study indicated these results are consistent over a 10 year period (Nakagawara and Montgomery, 2000).

Flight Discipline. This term refers to the adherence to rules, regulations, policies and operating procedures expected in a given flight regime. Lack of flight discipline, then, involves deviation from the above, usually in a deliberate, planned fashion, or proclivity for thoughtless impulsivity. Whether due to hormones, genetic disposition, cultural factors or a simple lack of aversion to risk, flight discipline violations seem to be an exclusive domain of males. To a large degree, this is simply a matter of preponderance of population numbers, but one would expect at least some female representation in flight discipline caused accidents, however there are virtually none (Kern, 1998). The picture for FAR flight violations is not as clear, since this category mostly includes blunders, typically without enough additional details to categorize them. Overall, flight discipline issues seem to reflect the same patterns of behaviors found in the greater society.

Pregnancy and Menses. These are the two most distinguishing characteristics between male and female aviators. Both raise issues that are of concern in an aviation environment. Of the two, pregnancy is by far the most consequential, since the well-being of not one but two individuals, at a minimum, are at risk. Many questions are unresolved, at least to the extent of consensus regarding flying activities. Obviously, at some point in a pregnancy, a woman must quit flying. To a large extent, this is dictated by the type of flying environment in which the woman participates. For example, a high-stress, high "g" environment, such as aerobatic routines requires a conservative approach, as does any flying where the use of

an ejection seat or a parachute is a possibility. All of the U.S. military services allow (but do not require) women to fly when pregnant, with increasing restrictions in the later stages, primarily the last trimester. Although the FAA arbitrarily requires airline pilots to cease piloting commercially at age 60, regardless of health, no such restriction is imposed on pregnant pilots, despite indications some might be prudent. For example, in the general U.S. population, one out of seven women will spontaneously abort during the first 12 weeks of pregnancy (S.A. Gilchrist, M.D. personal communication, September 20, 1999) and there is no reason to believe the incidence of occurrence is less among the female pilot population. High levels of pain, hemorrhage, incapacitation and even loss of consciousness typically accompany miscarriages, conditions which obviously impair pilot performance. This is in addition to common pregnancy side effects, such as morning sickness, which results in nausea, vomiting and fatigue, as well as premature labor in the latter stages (Anderson and Lunde, 1990).

In addition to the health of the mother, the health of the fetus should also be considered. While the fetus is naturally protected from one of the most common aeronautical hazards, hypoxia (Gilchrist, 1999), the risk to the fetus in accident situations is greatly elevated. A series of animal experiments were funded by the FAA to assess the best ways to seat pregnant women (in this case, passengers) to minimize dangers. Pregnant baboons were used in the experiment because of uterine and placental similarities to human females. A rail-mounted decelerator was used, with seat configurations varying between lap belts only, shoulder and lap belts in combination, and rearward facing seats. For the 11 baboons in the test the following results were recorded: (1) None of the adult baboons were killed in the crashes; three had significant trauma injuries. (2) All of the fetuses died on impact or shortly thereafter. Three died of head injuries, and the rest died of shock, hemorrhage, traumatic separation of the placenta or of unknown causes (Crosby, Snyder, Snow, and Hanson, 1968). Clearly this has implications for pregnant pilots, especially since these results were recorded without the additional hazard of a yoke and control column aimed at the abdomen.

Regarding menstruation, much of the inquiry data on this topic is controverted, since it tends to be viewed in political terms. Some studies indicate that female flight attendants recorded significantly more sick day absences from work than did female pilots (Rayman, 1996). Since there is nothing to indicate that females pilots differ physiologically from flight attendants, presumably the difference is attributable to motivation, with the conclusion that it is probably more rewarding to fly a jet than to push a food

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cart up and down the aisles.

Reaction Times: It has long been known that females have a small but measurable reaction time advantage over males (Goeters and Eissfeldt, 1990). This is a useful trait in the aeronautical environment, especially when one is faced with an emergency situation where even a split second can be critical.

It should be clear from the foregoing that there are real differences between male and female aviators, with advantages and disadvantages affecting both. The extent to which these characteristics can be resolved by technology advances is relatively limited, but prospects for future improvements are good. □

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APPENDIX

Percent of Subjects Whose Maximum Force Was Below Mil-F-8782B Design Requirements

Control	Criteria (lbs)	Percent Below Criteria	
		Males	Females
Stick Forward	75	0	28
Stick Back	50	0	40
Stick Left	35	5	95
Stick Right	35	50	100
Left Rudder	180	7	11
Right Rudder	180	0	5

From McDaniel, J.W. Male and female strength capabilities for operating aircraft controls. Preprint of the Scientific Program of the Aerospace Medical Association Meeting. May 4-7, 1981;12