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Research Paper

Women in Fighter Cockpit: A Review with IAF Perspective

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ABSTRACT

Introduction: On 08 October 2015, then Chief of the Air Staff Air Chief Marshal Arup Raha announced that IAF was planning to induct women into the fighter stream to meet the aspirations of young women in India. This statement heralded a new era in Indian Air Force as soon three women cadets were selected for fighter stream who are presently posted in IAF as fighter pilots. This article presents a comprehensive review of various historical, physiological, medical and social aspects which determine entry of women in fighter flying. ***Materials and Method:*** The MedIND, Pubmed and Google Scholar databases were reviewed for articles related to gender differences in attributes required for adaptability to aerospace environment. ***Discussion:*** Various aero medical concerns related to women health and pregnancy have been discussed to highlight its effect on flight safety. Careful planning and execution can obviate most of the concern and women can perform effectively in high performance jet cockpit. ***Conclusion:*** Entry of women into a domain hitherto fore exclusive to males is likely to change the attitude of IAF and society at large towards women. Women can effectively fly high performance jet aircraft without jeopardising flight safety due to gender differences in physiology.

Keywords: *Women, Fighter Flying, IAF, Aeromedical issues*

With the Indian Prime Minister showcasing women power during Republic Day parade to the world, the debate was rekindled whether women should be allowed in all the branches (including combat) of armed forces. Women world over have proven their mettle in all the challenging fields which were earlier considered to be solely for men. Indian Armed Forces opened their door for women in 1992 when the first batch of women Short Service Commission officers got commissioned.

Indian women had started showing up their presence in aviation sector in civil quiet early where in 1932 Urmila K Parikh became the first Indian woman to get pilot license. In 1948, Prem Mathur became the first Indian woman commercial pilot and started flying for Deccan Airlines.1n 1985, Captain Saudamini Deshmukh commanded the first all women crew flight on an Indian Airlines Fokker friendship F- 27 on the Calcutta- Silchar route. She also commanded the first Boeing all- women crew flight on September 1989 on the Mumbai- Goa sector. In 1990, Captain Nivedita Bhasin of Indian Airlines at young age of 26 became the

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youngest pilot in civil aviation history to command a jet airliner. It is estimated that at present Indian civil aviation sector has better women presence then global average. According to International Society of Women Airline Pilots, the percentage of women pilots globally is 5.88% whereas a conservative estimate of women pilot in India is 11% which is double the global average (1). Even though Indian women were proving their mettle in Civil aviation sector, they could not do so for Indian Air Force till Mar 1993 when the first batch of seven women cadets were commissioned for flying branch. In 1994, Flt Lt Harita Kaur Deolof IAF became the first woman to perform a solo flight in IAF. Even though IAF had opened its door for women pilots, they were allowed to fly only helicopters and transport aircraft without any combat role. Subsequently, women pilots were allowed to be in combat role in helicopter stream where two of its women pilots Flt Lt Alka Shukla and Flt Lt MP Shumathi were trained in flying twin engine Mi-8, a utility and medium size assault helicopter. However, flying a jet fighter was still a distant dream for Indian women till recently.

The representation of women officers in the armed forces has increased progressively since the year1993. As per the written reply submitted by the Defence Minister of India in the Rajya Sabha, the percentage of women officers in Indian Army, Indian Navy and Indian Air Force (excluding medical streams) was 3.3%, 3.9% and 10.04% (2). Presently, women are allowed in all branches of IAF including fighter flying.

The gender differences in various attributes viz. cognitive performance and good judgement (perhaps the most important attribute for a military pilot), effect of biorhythms on cognition, spatial abilities, physical, physiological and medical differences affecting the ability to withstand various aviation stressors has been advocated for combat and fighter flying restriction for women pilots in IAF. Apart from this, there are many other issues related to the issue of women in the cockpit, such as public opinion, effects of women on unit esprit de corps,the psychological fitness of women for combat, fairness to women in career advancement, etc (3).This article endeavour to discuss some of the key gender specific peculiarities in high performance jet cockpit.

METHODS

The MedIND, Pubmed and Google Scholar databases were reviewed for articles related to gender differences in attributes required for adaptability to aerospace environment. Key words used to search articles were women and aerospace or aviation, female in aviation, fitness, acceleration, physiology, performance and aviation stress. Scientific literature thus retrieved were reviewed for physical issues (viz anthropometry, anatomy, size and fitness difference in strength relevant to performance in military cockpit), physiological issues (acceleration, hypoxia, thermal stress, decompression sickness, motion sickness, ejection), medical issues (gynaecological issues, pregnancy, injury potential, illness potential, effect of hormonal changes on aviation stressors and possibility of medical incapacitation due to them and effect of long term exposure to radiation) and psychological issues (squadron culture, incidence of psychological illness, effect of mixed gender crew on group dynamics, public perception on women in aviation).

RESULTS

Physical Issues

Anatomy:

Gender differences in anatomy of male and female exist mainly in overall body composition (i.e. percentage body fat and its distribution), genito-urinary and breast anatomy.

A person's total body fat percentage is the weight of the person's fat divided by the person's weight, which reflects both essential and body fat. Essential fat is that amount of fat necessary for maintenance of life and reproductive functions. Essential fat is 2- 5% in male and 10- 13% in female. A certain percentage of body fat is essential to human functions such as – insulating internal organs and tissues, regulation of body temperature and as energy storage. Storage fat consists of fat accumulation in adipose tissues (store energy in the form of fat) part of which protects internal organs in the chest and abdomen. The American Council on Exercise has categorised ranges of body fat percentage as Essential fat (10- 12% for women and 2- 4% for men), Athletes (14- 20% for women and 6- 13% for men), Fitness (21- 24% for women and 14- 17% in men), Acceptable (25- 31% for women and 18- 25% for men) and Obese (> 32% for women and > 25% for men) (4).

Women differ from their male counterparts in distribution of body fat as well. Fat is distributed more in the buttocks, thighs and hips in women whereas it is distributed more in and around abdomen and waist. Muscle mass is also less among women in comparison to men.

These factors lead to significant differences in anthropometry, physical capacity, thermoregulation, ability to tolerate high G environment and propensity to Decompression Sickness (DCS), which have been discussed subsequently.

Genito- urinary anatomy of women may affect collection of urine in-flight during long-duration flying as the urine collection device in present aircraft is meant for men. Diapers and diaper like devices have been successfully used by women aviators in US. Similar devices called Disposable Absorption Containment Trunk (DACT) have been used by NASA in full pressure suits up-to 10 h without sequelaevizskin problems. Similarly, use of tampons with DACT has been evaluated for use during menstruation and no difficulty is envisaged (5). These modalities can be effectively utilised by Indian women pilot as well during long duration fighter missions.

Female breasts vary in sizes and with age, marriage, pregnancy and lactation which can have potential implications on fitment of flying clothing and safety harness. In a recent anthropometric survey in IAF, chest circumference (expiration) among female aircrew varied from 75.5 cms (1^{st} percentile) to 100 cms (100^{th} percentile), corresponding figure for male aircrew were 79 cms and 115 cms respectively (6). This shows that fitment of flying clothing may not be a big issue. The pliability of the breast may make restraint less effective; a larger range of size may be required. However, these concerns have been proved unfounded in actual flying. Riding up of the parachute harness during parachute opening shock has the potential of breast injury if the harness is not fitted properly. This can be prevented by careful fitment of harness (5). Breast discomfort under G have been speculated and reported variably. In a series of 102 women studied in a centrifuge, no breast discomfort was reported by Gillingham (7). On the other hand, Nava the et al found breast discomfort in 17% of their subjects (8).

Breast implants are becoming common surgery and most common indications are hypomastia, tubular breast, breast reconstruction and cosmetic correction. Females with hypomastia may be eliminated during selection but rest of the indications for augmentation mammoplasty will pose a question on flying worthiness of a female fighter pilot. Augmentation mammoplasty can be done using silicone gel implants, saline-filled implants or double lumen implants. The aero medical issue posed by breast implant is risk of rupture

or shifting of implant due to compression from high G environment, ejection/ egress or life support equipment. This has a potential to cause pain and distraction during flight, however, no such complications have been documented among female military aviators. Effect of ambient pressure is expected to be negligible as implants are closed fluid or gel device without trapped gas. An in- vitro study showed insignificant bubble formation in both silicone and saline implants at an altitude of 30,000 ft immediately following prolonged hyperbaric exposure. Implants volume increased slightly but none ruptured and bubbles resolved spontaneously (10). Post- op complications may result cause for prolonged grounding. Long- term health effects are not yet fully known. Silicone implants, injections or saline inflated implants in breasts for cosmetic purpose is disqualifying for all classes of flying in the USAF, however, waiver potential is good if there are no significant post- op complications. All serving female aircrew can return to flying after nine month of surgery. It is not disqualifying in the US Navy (fit six weeks after surgery) and US Army. AIMWTS review revealed a total of 115 cases for breast implants/ augmentation (7 FC I cases, 20 FC II cases and 88 FC III cases), all but 6 cases were given a waiver (11). There's no policy on breast implants in IAF.

Anthropometric Concerns

There is paucity of data on female anthropometry that can be utilised for cockpit design. IAF data is limited to that collected after induction of women into the IAF (6, 12). Anthropometric parameters are higher for IAF women in comparison to civilian population due to entry criteria in particular and nutritional and health status in general. On comparison with recent IAF anthropometric survey and a civilian data it revealed that 1^{st} percentile of stature of IAF women aircrew corresponded between 75^{th} and 95^{th} percentile of civilian women, weight and crotch height corresponded between 25^{th} and 50^{th} percentile (6, 13). Though both the studies utilised different methodology for anthropometric measurement but they do give us an idea that available anthropometric data is not representative of Indian women and cannot be utilised as selection criteria or for cockpit design.

Data from world literature indicates that the 50^{th} percentile woman is approximately similar to the 5th percentile man (3).In general, females are smaller on average than males across all parameters considered important in the cockpit. These include sitting height, buttock-heel, buttock-knee and functional reach. There is also an interaction between size and strength, as problems of reduced strength will be compounded when maximum force is required at maximum reach. It is estimated that the average cockpit designed for 5th to 95th percentile male would exclude about 50% women. This would be further compounded by the fact that our aircraft are imported and have been designed for the Caucasian male who is relatively larger than the Indian male. This may further reduce the percentage of women who might fit into the cockpit. The range of body sizes that can be accommodated by modern aircraft cockpits is limited by many factors. Ejection seat-equipped aircraft, for example, are generally designed with adjustment of the ejection seat being possible only in the up-and-down direction with no forward and aft adjustment possible. Rudder pedals are designed to be adjusted, but control stick, throttle and other controls are not. Accommodating a greater percentage of women would involve extending the design range. Increasing this range would require re-designing of cockpits and would drastically increase cost of designing aircraft (3).

While there is a general relationship between 5th percentile male and 50th percentile female, this is not exactly true. A same size female has smaller hands and smaller reaches, while having larger hips and a deeper chest. This would require changes in cockpit geometry and flying clothing. A similar mismatch is expected in the sizing and fitment of helmets. One

projection indicates that with fitment inserts, the smallest helmet would ride high on the female head and would thus be more likely to be displaced during Gz acceleration and ejection(3). This would be further compounded in the presence of HMSD and NVGs.

Physical Strength

Women are considered weak in terms of physical strength. Hand grip is one of the most widely used markers of strength. The strongest 10% women can only beat the bottom 10% of men in hand-grip. Depending on the muscle group, females have only between 35 and 85 percent of the strength of males. Women's lower limb strength is ~72% of males, the upper limb strength is only ~55% (14) This can be improved somewhat by weight training, however, the effects of weight training in female student pilots has not always produced benefits. When women first began flying training in the US Navy they were scheduled extra physical training sessions as part of their curriculum. This was in fact found to be detrimental to their training as it distracted them from studies and actually produced no real benefits in terms of strength (15).It was a cause for concern for the ability to operate aircraft controls especially in emergencies. It has been hypothesized that females may be unable to operate aircraft controls in the event of hydraulic failure. This concern has been raised even for more modern aircraft, such as the C-130 Hercules (18). However, in modern cockpits with fly by wire controls this has ceased to be a cause for concern. Similarly, initiation of ejection requires a reasonable degree of physical strength which female aircrew may lack especially under high G environment. Though author couldn't find any specific study examining these issues, there is a general consensus that most people will have the strength to initiate the ejection sequence in an emergency. Ejection sequence requires pulling of parachute ripcord in the descent phase when automatic initiation fails or manual override is required. A civilian study in Australia revealed that women find it difficult to exert the 10 kgf required for pulling parachute ripcord (17). This has resulted in a considerably higher fatality rate in women parachutists, half of which are due to inability to deploy parachute. This may be a cause for concern.

Manoeuvring an aircraft and performing an anti-G straining man oeuvre (AGSM) in a high G environment require a high degree of muscle strength and endurance. This implies that a greater percentage of women compared with men will experience difficulties in this area. However, it is also true that a percentage of men as well will have difficulties, particularly when flying at the aircraft limits. Fitness to fly high-performance aircraft should be decided on a case to case basis, with the acceptance of the fact that not all people are capable of flying all types of aircraft and all types of missions. As well as assessing the ability to fly the aircraft, several occupational health and safety considerations may be of concern due to these strength differences. These include the potential for neck injury under high G loads and the ability to initiate the ejection sequence in an emergency.

Females have decreased neck strength compared with men (60%) but have a 12%greater range of movement and 11% faster neck muscle reaction time (16).Since all these three factors play a role in determining resistance to injury under G, the overall risk of neck injury is believed to be similar for both genders.

Aerobic Fitness

Women typically achieve VO_2max scores 15 to 30% below males. This has been ascribed to differences in body composition and hemoglobin concentration. As has been mentioned above, women have a higher percentage of body fat, and VO_2max corrected for lean body

mass is similar for males and females. Thus aerobic fitness is not likely to be a cause for concern in aviation.

Ejection

Lt Linda (Heid) Maloney of US Navy was the first women pilot to eject from an aircraft who survived without any significant injury. Despite this, injuries due to ejection forces are a major concern for women fighter pilots. Women in child bearing age have lax ligaments (effect of oestrogen hormone) leading to joints instability which is considered to be the cause for high sporting injuries. There is higher incidence of lower back pain among women as their spine has to support weight of the breasts. Further, bone mass is 50% lesser among women than in men and they lose bone density faster as they age. However, ejection injuries are known to occur more among heavier and taller individuals which is in favour of women fighter pilots as they are shorter and lighter than their male counterparts.

Forces involved during ejection from a fighter cockpit challenges the physical strength of vertebral column which in turn decide the injury potential of an individual. Cross-sectional area of vertebrae is most significant anatomical factor dictating the ability of human spine to withstand these forces. Females are lighter and have a smaller cross-sectional area of vertebrae compared with same size males. Since seat charges are designed for them ale weight range, female vertebrae are exposed to a greater force per unit area than those of same size males. This suggests an increased risk of spinal column injury in females. However, the same couldn't be confirmed by the experimental evidences. A manikin's based study demonstrated that the risk of vertebral fractures was significantly greater with smaller mass dummies (19). At the same time a statistical analysis of real life ejection data revealed that the risks of vertebral fractures were increase din taller and heavier ejectees (20).The calculation of Dynamic Response Index (DRI) indicates that the 5th percentile woman (~45 kg) may have a fourfold higher chance of spinal injury than the 5th percentile man (3).Fourth generation ejection seats like K-36D3.5E (Su-30MKI) caters for smallest weight of 50 Kg to highest weight of 120 Kg and has significantly reduced the jolt experienced by the human spine reducing the possibility of spinal fractures. Due to this the overall risk for females is probably not unacceptable. However, majority of IAF aircraft have older Martin- Baker seats which may have unacceptable injury potential for women aircrew. Regular training in ejection test rig might be able to offset this possibility.

Other differences in shape between females and males may result in an increased risk of other injuries, such as fracture of the femur and landing injuries, however, this couldn't be conclusively proved in any study.

The post-menopausal effects on bones and the possibility of osteoporosis leading to increased injury potential may be a cause of concern in aging women aircrew. Hormone replacement therapy may be mandatory for post-menopausal women to counter these effects.

Speech Intelligibility and RT Communication

Acoustic speech signal differs in men and women which may affect speech intelligibility in high – noise environment of aviation activities during radio telecommunication. This may have serious implications for high-performance fighter flying. Anecdotal information, supported by some empirical observations, suggests that some of the high intensity noise spectra of military aircraft cockpits may degrade the intelligibility of female speech more than that of male speech. However, a study in which the intelligibility of female and male speech was measured in several high level aircraft cockpit noise conditions experienced in

military aviation concluded that speech intelligibility of both genders was acceptable during normal cruise noises however, improvements are required in most of the highest levels of noise created during maximum aircraft operating conditions (21).

PHYSIOLOGICAL ISSUES

Due to physical differences and speculated physiological differences it was suspected that women may not be able to survive various aviation stresses encountered during high performance fighter flying. However, review of literature suggests no significant physiological differences between the two genders which will compromise capability to fly fighter aircraft.

G-Tolerance

Acceleration (G) stress is a significant factor in high performance fighter flying. No significant differences in relaxed or straining G tolerance were noted between the sexes in series of centrifuge studies (22, 23).G tolerance has a strong negative correlation with height and a weaker positive correlation with weight. When height and weight are eliminated as factors, there is no significant gender effect on Gz tolerance. Heaps showed that SACM tolerance of female subjects was same as male subjects (24). This study also examined performance across the menstrual cycle in women on the oral contraceptive pill. It had been postulated that the theoretically increased vasodilatation seen as result of an oestradiol surge during the mid-follicular phase may have resulted in a slightly reduced tolerance, however no significant difference was noted (24).Many studies have shown the potentially damaging effects of oscillatory motion on breast tissue, however breast discomfort has not been reported in centrifuge studies and there is no evidence that unidirectional motion is likely to cause long term damage (9).The Gillingham study deliberately screened out women with pre-existing gynecological conditions however two of the 24 women in the study reported urinary incontinence whilst undertaking an Anti-G Straining Man oeuvre. This symptom has not been reported in men. This unique problem encountered by the women was compared to two cases of scrotal hematoma out of 544 individuals who rode on the USAFSAM centrifuge (25). The effect of G on the uterus in older women and on in situ intrauterine devices has also not been adequately studied to date, nor have effects on menstruation. Electrocardiographic changes seen in females during + Gz stress were similar to those seen in males (26).

Hypoxia

Females have smaller values across a wide range of lung parameters and generally have smaller lung capacities than males. Females also have several haematological differences including reduced haemoglobin, and therefore oxygen carrying capacity, compared with their male counterparts. However, women exist at sea level under normal circumstances with these differences and presumably have similar coping mechanisms to men when exposed to hypoxia. Absolute tolerance to hypoxia is difficult to determine and consequently literature is scant on gender differences in hypoxia tolerance. Most studies in this area have been performed in mountaineers and have therefore, focussed on chronic hypoxia. These studies have demonstrated no real difference between the sexes in terms of overall acclimatisation although some minor differences in response have been reported (27). In fact, women appear to tolerate chronic hypoxia better and have also been shown to be less susceptible than males to the symptoms of Acute Mountain Sickness (28). The limited studies comparing the response of males and females to acute hypoxia have shown little difference in performance between the sexes at altitude relative to their differences at sea level (29). However, exercise tolerance in hypoxia has been measured for males as well as females. Conditioned females,

like their male counterparts, have a larger drop in VO2max than non-conditioned females. Use of oral contraceptives for one month is known to reduce tolerance to hypoxia (30).

Decompression Sickness

As brought out earlier, females on average have increased body fat compared with males, which leads to an increased nitrogen load. Apart from this, hormonal changes occurring with the normal menstrual cycle or due to the oral contraceptive pill may result in reduced venous tone which may exacerbate the effects of nitrogen bubbles. For these reasons feminine gender appears to be more susceptible to Decompression Illness (DCI) compared with men, with reported increased incidences of between three and four fold in both Altitude induced and diving DCI. Studies have also shown that females not only presented with more symptoms of DCI but also were more likely to present with complicated DCI (31,32,33). There is an apparent increased incidence of DCI in early stage of menstrual cycle as well (34).

Despite these differences, DCI is still a relatively rare event in aviation to the extent that IAF has not reported any case of DCI so far, and therefore, even with this increased risk, the overall risk of female aircrew developing DCI when flying is still acceptably low. The risks associated with chamber training are however of some concern but still acceptable considering nil incidence of DCI during chamber training in IAF.

Response to extremes of thermal environment

Cold environments are also encountered in aviation, especially in the survival situation. Females are known to possess a better tolerance to cold than males, perhaps due to their greater than average fat stores. On average females contain 25% fat whilst men only contain 15% and these differences remain even with physical training (35). Thus, females have greater buoyancy, insulation and energy stores compared with males and are therefore better prepared physiologically in a survival situation, particularly at sea. However, if controlled for percentage fat (and especially fat distribution), there is probably little difference between the sexes (36). On the other hand, there appears to be no difference in the heat tolerance of acclimatized males and females.

Acclimatized men and women of similar fitness shows no operationally significant gender differences in heat tolerance (37,38,39,40). There is an evidence to suggest that fit women acclimatized faster than fit men (40). Heat tolerance may be affected by hormonal changes during menstrual cycle which leads to a small cyclic shift in rectal temperature regulation, resulting in slightly higher rectal temperatures with exercise during the mid-luteal phase of the menstrual cycle. However, this shift of less than 0.5º C is unlikely to impact heat tolerance more than aerobic fitness, acclimatization, or individual variation (41).

Motion Sickness and Simulator Sickness

Questionnaire studies have shown that women are significantly more susceptible to motion sickness which further gets exacerbated during menstruation (42, 43). Differences have also been reported in rates of simulator sickness (44). Hormonal influences and other factors like field dependence have been proposed to be the reason behind these differences. In an unstable environment (for example when stationary in a moving environment), females are more likely to experience conflicting perceptual cues than males (45). Field dependency correlates well with both nausea and disorientation. This argument further gets strengthened by the fact that males are more stable than females on tests for ataxia such as Sharpened Rombergs (46). This can also be explained on the basis of women having a higher propensity to accept sickness, which men may not due to societal bias (43). This increased potential for

motion sickness and simulator sickness is of significance only at entry level where if trainees fail to adapt to motion environment are managed by motion sickness desensitisation with relatively good outcome.

MEDICAL ISSUES

Men and women have a different incidence and prevalence of many diseases of aeromedical importance. Few medical conditions like migraine, varicose veins and urinary tract infections are more common in females. Women report more symptoms and attend medical facilities more frequently than men (47). However, women have a lesser incidence of serious and potentially permanently incapacitating disorders such as ischaemic heart disease.

Illness capable of causing sudden in-flight incapacitation

Men appear to be at greater risk of in-flight incapacitation due to the higher all-cause mortality rate. As per 2012 census, Crude Death Rate in India for males is higher than females is (7.7:6.4). Female death rate is lower than male death rate both in rural and urban areas (48). The sex mortality ratio in India is maximal for 15- 59 yrs age group which is approximately 1.65 (4.3 M/2.6F). Of the ten leading causes of death in age group 25- 69 yrs, women are more likely to die in 5 leading causes. However, women is less likely to die due to the most leading cause of death (Cardiovascular disease) which forms the major chunk in the ten leading causes (26.3% for Males to 22.5% for females in this age group (49). The decreased frequency of coronary heart disease in women could make them a better risk than men from the point of view of incapacitation from medical causes. Further, Indian men are more likely to die due to unintentional injuries (5.0% for male and 4.1% for female) and intentional self-harm (3.3% for male and 2.6% for female). Male pilots have a higher rate of both fatal and non-fatal aviation accidents (50). In another recent study it was concluded that there should be no discrimination between male and female pilots, or between young and senior pilots up to 60 yrs of age with respect to their safety performance, as measured by the likelihood of pilot error (51).

It is widely believed that women report higher rates of morbidity, disability and health care use due to gender differences in the way that symptoms are perceived, evaluated and acted upon. It is widely assumed that women will be more ready to report illness and to seek help and that they have greater flexibility in their lives to accommodate illness. Contrary to the common expectation, in a questionnaire based study on chronic illness, there's no gender difference in the initial reporting of morbidity and mental health problems (52). In a study done on aviator population, the U.S. Army found that women accounted for 6.7% of aviation medical losses while accounting for only 1.2% of the aviator population; one-third of female losses were due to pregnancy (53). This impact is likely to be more palpable in IAF as the female aircrew population is 2.9% at present (6). However, author couldn't find any Indian study to corroborate or refute this assumption. Women are more likely to sustain injuries than men (51% for women and 27% for men) when exposed to the stresses of basic combat training. However, when these percentages were adjusted for fitness level as measured by mile run time and number of push-ups performed, however, the male/female differences disappeared (54).

Aviation environment may differentially cause disease in women in mainly three areas- v.i.z cancer caused by radiation exposure, menstrual irregularities and psychiatric illness. Radiation is a potential hazard of high-altitude flight which depends on altitude, latitude, hours aloft and solar activity. Exposure to ionizing radiation causes an increased risk of cancer of all types roughly proportional to the magnitude of exposure, although the exact

shape of the dose response curve is unknown. Due to this reason, NCRP and ICRP have considered aviators to be radiation workers for higher maximum permissible dose (MPD) than general population and has defined annual MPD (50 mSv as per NCRP and 20 mSv as per ICRP) and life- time MPD (10 mSv x age). MPD for a pregnant aircrew is one tenth of annual MPD. Differences in male and female anatomy and physiology may affect the epidemiology of radiation- induced disease. Various studies have brought out that British airways pilots had six times greater risk of Malignant melanoma, myeloid leukaemia was four times more common among Canadian pilots, Astrocytoma occurred twice in pilot groups and prostate cancer was significantly higher than general population. A study of female airline flight attendants in Finland and Denmark showed an increased incidence of breast cancer possibly due to exposure to magnetic and cosmic radiation (55).

The stress associated with high performance fighter flying can affect menstrual cycle which has been documented among athletes as menstrual irregularities and not as pelvic discomfort (56). Dysmenorrhoea is known to aggravate migraine, tension headache and sinus headache and may result in loss of effectiveness during this period. Depression and irritability is one of the hallmarks of onset of menstruation in many women. However, it can be effectively managed by use of OC pills and analgesics in most of the women.

Psychological profile of a women aviator may not be much different from their male counterpart as suggested by studies of both civilian aviators and air traffic controllers which demonstrated them to be more like their male counterparts than the population as a whole in their psychological profile (57,58). Males are more aggressive, which can be beneficial in combat. But that trait also leads to more accidents and injuries, up to and including eye injuries (men in the military have twice as many as women) and suicide (men account for about 95% of military suicides). Women are more nurturing, and their most basic form of nurturing – motherhood – accounts for 58% of hospitalizations among active-duty female troops. But they also crash and kill themselves much less often. While women have accounted for about 10% of the U.S. forces deployed into the post-9/11 wars, they represented less than 13% of those medically evacuated – pretty close to their share of the force (battle injuries represented only about 15% of the total). Differences in how men and women reacted to repeated combat deployments are slight; PTSD levels were similar. Male troops drank more, and females had greater difficulty adjusting once back home (59). A study done on ADAF suicide deaths between 1990- 2004 revealed that there were significant deficits of suicides in overall enlisted personnel and in overall officers in comparison to general population. There were significant deficits only in enlisted men and officer men. Suicide mortality in enlisted and officer women was not significantly less compared to their general population counterparts revealing that stress of USAF service is not affecting women much in this regard (60). Gender based group dynamics, interpersonal relationship and concern for prisoner of war is a significant issue in the psychological aspect of assimilation of women aircrew in fighter flying. In a comprehensive anonymous questionnaire survey of all U.S. Army and U.S. Air Force rated female aircrew, with an equal number of age and duty matched male aircrew revealed that male and female military aircrew differ in the perception of their ability to function in mixed squadrons because of their gender. Some of these perceptions can be modified through training, others may need to be resolved through high level orders/policy; while in others, military may have to accept women are different from men in some aspects (61). Mapping personality of women aviators can be a solution to various complex issues in aviation. Using the "big five" personality structure (neuroticism, extraversion, openness to new experiences, agreeableness, and conscientiousness), female United States Air Force pilots were compared with both male Air Force pilots and to a female

comparison group. Female Air Force pilots were higher on the Extraversion, Agreeableness, and Conscientiousness scales than male pilots. Female pilots were also higher on these scales than the female comparison group and lower on the Neuroticism and Openness scales than that comparison group. It is suggested that these traits are highly adaptive for Air Force pilots, given the nature of modern military operational requirements (62).

Long- duration fighter flying is demanding and aviator fatigue is one of the major aeromedical concerns. A study examined responses of men and women to this operational stressor and sleep deprivation where pilots were tested on flight performance and mood during 40-h periods of sustained wakefulness. Gender produced no operationally-significant effects of flight performance or recovery sleep. Although mood tests showed that women felt less tense and more energetic than men, there were no interactions between sleep deprivation and gender on either flight performance or psychological mood (63). Further, risk of venous thromboembolism may be high in a women long duration fighter pilot in a cramped cockpit which gets further aggravated due to dehydration and OC pills.

Use of OC Pills

OC pills not only acts as a birth-control pill but also have multiple other benefits such as making menstrual cycle regular and predictable with short and light flow resulting in over all good health by reducing incidence of iron-deficiency anaemia, menstrual dysmenorrhoea, painful ovulation, premenstrual symptoms and cyclic breast pain. The OC pills have been cleared for use during flight by many air forces (e.g Australian Defence Forces) after ground trial of one month despite its potential cardiovascular side effects like stroke, thrombophlebitis and thrombo-embolism which get further aggravated by smoking. However, IAF does not permit flying with OC pills.

Pregnancy

Pregnancy leads to major changes in physiological and body morphology of women which is an aeromedical concern during all three trimesters due to either its effect on ability to perform in-flight duties or effects of aviation environment on the foetus. The risk of early spontaneous abortion (which is up to 15% in first trimester), ectopic pregnancy, dehydration and malnutrition due to morning sickness is a major aeromedical concern in first trimester. Effects of hypoxia, +Gz acceleration, exposure to radiation & aviation toxins and vibration on developing foetus are not fully understood. Ergonomic issues like fitment of flying clothing, harness and other safety equipments is a major concern in second and third trimester. Due to these reasons, IAF grounds all women pilots the moment pregnancy is confirmed. If percentage of women fighter pilots is significant than this is likely to affect operational preparedness adversely as such women pilots are likely to be out of duty for long (close to two years including maternity leave of six months authorised to them). However, a careful planning and proper career counselling my help in keeping this situation under control.

SOCIO-CULTURAL ISSUES

Indian Armed Forces which is reflection of its society has not allowed women in combat. However, women are serving in defence under non-combatant capacity, doctors and nurses for long. There is indication that IAF aircrew are pro-feminist and have egalitarian attitude towards them (64).

Squadron Bonding

There is an apprehension that presence of women will affect the ‘squadron bonding’ or ‘unit cohesion and therefore reduce mission effectiveness. Despite the fact that women are already

flying transport and helicopters in IAF, 59% of respondent in a survey opined that women should not be allowed in fighter flying. Despite the fact that 76% of them believed that women were not hindrance in the working of the squadron, only 48% of respondents were comfortable working with women in squadron/unit/cockpit (64). Perception and attitude is known to change with changes in regulations as now women have been allowed to fly fighters in IAF.

Escape & Survival: Prisoner of War (POW)

Chances of escape and survival from a hostile territory depend mostly on the mental strength and training of the military aviator. Gender may not have significant role to play except where physical strength is decisive. The possibility of customary and sexual abuse is extremely high if taken as POW. However, women who join fighter flying have accepted this risk willingly. The risk of ejection and sustaining debilitating injury in peace-time is equally scary and probably higher. The women who choose to join fighter flying are different from their civilian counter-parts. Most former Prisoners of War usually recover fully from the physical and psychological stresses and that many prisoners of war find a lasting emotional strength from their experience (65).

Protective Instinct

It is widely believed that male members of a unit will be more protective of the female members in both combat and/ or capture situation, thereby, compromising the mission outcome. Soldiers are known to sacrifice their lives for other team/ unit members and even if this concern is true should not be taken negatively.

Public Perception/ Outcry

It is a common perception that public outcry will be more if a women pilot is taken as POW or mistreated during hostility. However, the public conscience is built-up by media and society at large. This is likely to change as women performs such duties. Such outcry, if any, is unlikely to be out of proportion of the issues at hand during such hostilities.

CONCLUSION

There are three women fighter pilots flying fighters in IAF as on date. More are likely to join in the future. There is little science and more of social perception in not allowing women in combat roles in general and fighter flying in particular. All the concerns related to fighter flying by women can be addressed by use of training, selection and technology. Women are no different from their male counterparts in their ability to fly fighter missions.

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Conflict of Interest

The authors colorfully declare this paper to bear not conflict of interests

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