



**The Medical Implications of Women On Submarines**

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# **The Medical Implications of Women On Submarines**

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Report No. 1219

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A handwritten signature in black ink that reads "M. D. Curley". The signature is written in a cursive style with a large, sweeping "C" and "y".

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# Medical Implications of Women on Submarines

## EXECUTIVE SUMMARY

### Background:

US Submarines maintain an all-male force. The Defense Advisory Committee on Women in the Service (DACOWITS) recommended, after the Spring 2000 conference, the assignment of female officers to TRIDENT class submarines. As of June 2000, women comprised 14% of Navy personnel strength with 25% of these on ships. Combat vessels were opened to female sailors in 1994 following congressional repeal of the "Combat Exclusion Law." Submarines remain exempt citing, among other issues, the prohibitive costs of berthing and privacy arrangements. Placing women on submarines, moreover, raises medical considerations that require critical consideration. Research is needed to better elucidate the impact on not only the individual female's health but also on the submarine's mission effectiveness.

### Approach:

Personal communication with the medical representatives of various foreign navies as well as at the National Aeronautics and Space Administration (NASA) inform a brief discussion on how women have been integrated into submarines overseas and in space travel. An extensive literature review then explores gender differences in health care usage and in health problems traditionally problematic in submarines. The final section considers various gynecological and pregnancy related issues. Because the population of interest for this review is undefined, i.e. US Navy female submariners, literature concerning the experience of women on surface vessels as well as in the Persian Gulf War has been incorporated into the evaluation along with an extensive review of available general epidemiological data.

### Findings:

- Health care usage rates: Women use the health care system 1.6 to 2.6 times more than men for all categories of disease. Women require medical evacuation (MEDEVAC) 1.3 times more often than men.
- Cardiac Disease: Up to age 45, this is primarily a male disease. Of all myocardial infarctions, only 6-10% occur before age 45 and of these, only 5-10% are in women.
- Anemia: The prevalence of iron deficiency anemia in women is 3.1 to 4 times higher than in men.
- Asthma: Prior to puberty, asthma is more common in males. After puberty, women are diagnosed with asthma 3 times more than men.
- Headache: Migraines occur 3 to 3.6 times more frequently in women and are most prevalent in the 25-55 year old age group.

- Peptic Ulcer Disease: Men contract this 2.1 times more often than women.
- Gallstones: Women develop gallstones 2-3 times more frequently than men with an increasing incidence as they approach age 40. Cholecystectomy is required in 30% of patients with gallstones and is curative.
- Orthopedic Injury: Several military studies reveal an average 2.5 times higher injury rate in women for the same level of activity. This difference is improved with improved physical fitness.
- Osteoporosis: The submarine environment poses some theoretical risks for osteoporosis including decreased vitamin D levels from the absence of sunlight and a relative lack of physical activity. Carbon Dioxide levels are 10 times higher than normal and this may also lead to some bone loss. Women lose 50% of their bone mass over a lifetime compared with 35% for men leading to speculation that they may be at higher risk from these factors.
- Mental Health: In both the civilian and military communities, the amount of mental illness among men and women is approximately equal with men suffering from antisocial personality disorders and substance abuse problems and women suffering from affective, anxiety, and somatoform disorders. Women seek treatment more often. Post Traumatic Stress Disorder (PTSD) probably has a higher incidence in women. Women attempt suicide more frequently but men complete suicide more frequently. Women, especially military women, tend to have been exposed to sexual trauma more frequently than men.
- General Gynecology: Persian Gulf War and surface fleet literature indicate that gynecological problems accounted for 20-25% of women's visits. These studies indicate that the six most common categories are menstrual disorders, dysfunctional uterine bleeding, sexually transmitted diseases, pelvic pain, cervical disease and incontinence. In the Persian Gulf War, the most common reason for MEDEVAC out of theater was pregnancy.
- Pregnancy:
  - Manpower: Pregnancy rates in the Navy range from 0-27% depending on the type of ship surveyed with an overall average of 19%. In general, support ships tend to have higher pregnancy rates than combat ships. More pregnancies occur in the E1-E4 ranks. Most are unplanned.
  - Early Pregnancy Risk: Pregnancies may occur among a mixed gender crew if a female crewmember conceives prior to deployment but does not recognize the pregnancy until post deployment, or if she conceives while deployed, or if she intentionally conceals her pregnancy. Early pregnancy emergencies include spontaneous abortion (SAB) and ectopic pregnancy. Navy studies reveal a rate of 7-10% for SAB and 1.4-2.7% for ectopics. Both these conditions may require life saving surgery.
- Fetal Development: The submarine atmosphere, containing chronically elevated CO<sub>2</sub> and other contaminants, and submarine environmental factors such as noise and vibration levels, present currently unknown risks to the fetus. Carbon Dioxide levels in the submarine

usually run .5% with normal atmospheric levels of .03%. Animal experiments have shown deleterious effects to fetal offspring at levels of 6% and greater.

- Submarine Medical Support: Medical support and facilities onboard submarines are limited. The attack submarine Independent Duty Corpsman (IDC) works in a small, very cramped space without an examination table. Exams requiring the patient to lie down are conducted on the deck or on a mess table. Submarine medical communications are limited to carefully formatted messages sent only when absolutely necessary. The process of transferring an ill or injured patient to a higher level of medical care at sea is dangerous for the patient and crew and requires the submarine to surface, risking detection.

## **Conclusions:**

### Implications Affecting the Submarine:

- Women use healthcare more than men. As the number of women increase on a submarine, the demand for the IDCs time will likely increase. A second corpsman may be necessary.
- Women have higher rates of migraines, anemia, asthma, and gallbladder disease. Men have higher rates of heart disease and peptic ulcer disease. Manpower losses due to these submarine and radiation health-disqualifying conditions may increase as will the generation of waiver requests.
- Women have a higher rate of orthopedic injury than men do but men tend to participate more frequently in injury-prone sports. The net effect on the ship's medical support will likely be negligible.
- Men and women suffer from an approximately equal overall incidence of psychiatric disease. Overall, the increased tendency to seek treatment, the increased incidence of PTSD, the increased rate of suicide attempts and the type of disorders from which women suffer suggest that the need for psychiatric evaluation and disposition may increase if women are assigned to submarines. An additional concern is the high rate of pre-service sexual abuse or assault suffered by military women and how this would manifest itself in the closed submarine environment. Potentially, effective screening could lower the rate of psychiatric difficulties in female submariners. Modification of the submarine psychiatric screen for use with women is essential.
- General gynecological complaints include menstrual disorders, dysfunctional uterine bleeding, pelvic pain, sexually transmitted diseases, cervical disease and incontinence. Effective submarine medical support will require training and facilities to deliver care for these diagnoses. The development and use of appropriate gynecological management algorithms is needed. Authorized Medical Allowance Lists (AMALs) also need review and modification.



- Manpower losses because of pregnancy will occur and be problematic for submarine staffing. The effect of a strongly motivated, more mature, volunteer population of females may well reduce this type of loss.

#### Implications Affecting the Woman's Health:

- Studies indicate three potential risk factors for osteoporosis on submarines: lack of sunlight leading to decreased vitamin D, relative inactivity, and chronically elevated atmospheric levels of CO<sub>2</sub>. Because of a woman's natural rate of bone loss throughout her life, she may be at increased risk for osteoporosis due to service in submarines. The effects of these risk factors in a pre-menopausal population of women require further research.
- The risks of ectopic pregnancy and spontaneous abortion need further study. Submarine communication and MEDEVAC problems present significant challenges in the management of these emergencies. Rigorous pre-deployment screening will likely minimize underway pregnancy but cannot guarantee its absence.
- Risks to the developing fetus are at present unknown. Categorical reassurance cannot be given that the submarine environment is safe for a developing fetus. Extensive animal research is needed.

#### Research Requirement Recommendations:

##### Submarine atmosphere effects study.

Evaluation of the potentially toxic effects of submarine atmosphere contaminants and elevated carbon dioxide levels using multigenerational studies.

##### Bone health study.

Animal and human research on bone health investigating the impact of elevated carbon dioxide, the absence of sunlight, and the relative inactivity of the submarine environment

##### Epidemiological studies.

- Initiation of an institutionalized submarine health surveillance program.
- An evaluation of submariner morbidity and modeling studies on women's medical care needs to determine the impact of increased health care utilization, risk of ectopic pregnancy, spontaneous abortion, and pregnancy on the submarine service.
- Male submariner reproductive health study.

##### Medical care for women on submarines assessment.

An assessment of additional medical supplies and equipment, fixture modifications, medical procedures planning, and need for an additional corpsman to ensure adequate medical care for women serving onboard submarines.

Submarine screening test modification.

Research on modification and application of submarine duty psychological screen to females.

Training assessment.

Review and assessment of submarine IDC training curriculum and development of women's health management algorithms.

## **Medical Implications of Women in Submarines**

### **Introduction**

The Submarine Service and the Special Forces are the only two occupational fields that remain closed to women in the US Navy. At the end of their Spring 2000 conference, the Defense Advisory Council on Women in the Service (DACOWITS) recommended the assignment of female officers to TRIDENT class submarines. This paper focuses on the medical issues inherent to such a policy change. Through an extensive literature review, it examines the medical implications of women serving in submarines from two important perspectives; the impact of the submarine's environment on women's health and the impact of women's health needs on the submarine's medical department and thus on its mission.

The review highlights traditionally important medical conditions for submariners along with the unique consequence of women's healthcare on the submarine. The information covered includes a review of the history of women in the military followed by a discussion of how women have been integrated into submarines in foreign navies and in space travel. The bulk of the document, then, consists of a literature review that examines gender differences in health care usage as well as in health problems that have traditionally been problematic for submariners including cardiac disease, anemia, asthma, headaches, peptic ulcer disease, orthopedic problems, and psychiatric disease. Gynecological and pregnancy related issues constitute the final area of review.

The population of interest for this review is, as yet, undefined, i.e. US Navy female submariners, rendering a direct literature search unattainable. To overcome this difficulty, literature concerning the experience of women on combatant and non-combatant vessels as well as in the Persian Gulf War has been incorporated into the evaluation along with an extensive review of available general epidemiological data.

The important result of this work is to pose questions with the ultimate goal of identifying medical research needed to insure the continued safety and health of the US Submarine Force should mixed gender crews become the standard. Definitive answers regarding the medical prudence of assigning women to submarines are not presented in this review. Indeed, these answers remain unavailable at this time.

### **Background**

As of 31 July 2000, women comprise 14% of the Navy's 384,020 members. About 25% of these women are assigned to ships (116 combatants, 45 non-combatants, USNS ships, and deployed aviation related personnel).<sup>1</sup> SECNAVINST 1300.12B outlines additional opportunities for women in the Navy and Marine Corps and was written in response to the congressional repeal of the "Combat Exclusion Law" in 1993.<sup>2</sup> This instruction allows women to be assigned to combat units, platforms and vessels with the exception of those involved in direct ground combat, special forces units, and submarines as they are currently designed.

The Armed Forces Integration Act of 1948 gave women a permanent place in the military services by authorizing females in the regular Army, Navy, Air Force, and Marine Corps at a level of no more than 2% of total enlisted strength. Female officers could then number only 10% of enlisted female strength and could not advance beyond the rank of O-5 (Lieutenant Colonel or Commander). Congress repealed the limitation on female enlisted strength in 1969. In 1976, women were admitted to the three major service academies having already been admitted to the Merchant Marine and Coast Guard Academies by executive order. Two years later, Congress passed a law allowing women to be assigned to permanent duty on Navy vessels not expected to be assigned to combat missions.<sup>3</sup>

The Department of Defense (DoD) adopted the “Risk Rule” in February 1988. It excluded women from non-combat units or missions if the risks of exposure to direct combat hostile fire or capture are equal to or greater than the risk of the combat units they support.<sup>3</sup> This risk assessment came into focus initially in 1989 during Operation Just Cause in Panama when women were exposed to risk though not officially in combat. Desert Shield/Desert Storm witnessed a highly visible presence of women in the combat zone with resultant female deaths and the capture of American women by Iraqis.

The Defense Authorization Acts for 1992 and 1993 repealed the limitations of assignment of females to combat aircraft in both the Air Force and the Navy. The 1994 Defense Authorization Act then repealed the ban of women on combat ships. In January 1994, the Secretary of Defense (SECDEF) directed:

1. All services to permit women to compete for assignment in aircraft, including aircraft engaged in combat missions.
2. The Navy to open as many additional ships to women as is practicable within current laws. The Navy also was to develop a legislative proposal to repeal the existing combat exclusion laws and permit the assignment of women to ships that are engaged in combat missions.
3. The Army and Marine Corps to study opportunities for women to serve in added assignments including but not limited to field artillery and air defense.

Exceptions to the general policy of opening assignments to women included units engaged in direct combat on the ground, assignments where physical requirements are prohibitive and assignments where the costs of appropriate berthing and privacy arrangements are prohibitive.<sup>4</sup>

A follow-on memo by the SECDEF lifted the “Risk Rule,” defined direct ground combat, and listed specific exceptions. These exceptions included:

1. Where the service secretary attests that the cost of appropriate berthing and privacy arrangements are prohibitive.
2. Where units and positions are doctrinally required to physically co-locate and remain with direct ground combat units that are closed to women.
3. Where units are engaged in long-range reconnaissance operations and Special Forces missions.
4. Where job-related physical requirements would necessarily exclude the vast majority of women service members.<sup>5</sup>

In response, the Secretary of the Navy (SECNAV) submitted proposals for implementation of new assignments for women that identified the submarine career fields as the only area closed to women for reasons other than direct ground combat or collocation with direct ground combat forces. He directed the Chief of Naval Operations (CNO) to conduct annual reviews with a view towards accommodating women in this field to the fullest extent practicable in new and existing classes of submarines consistent with cost and the distinctive elements of service that exist for submarines.<sup>6</sup>

## **Foreign Navies**

Sweden, Norway, and Australia allow women to serve on submarines. Sweden has done so since 1991 with no provision for separate bunking or shower facilities. No medical representative is on board unless the submarine is transiting the Atlantic. Medical care as needed is supplied by the submarines' officers, who are trained in first aid. Pregnant women are transferred to shore duty (H. Gronkvist[hans.gronkvist@marinc.mil.se], e-mail, July 7, 2000). Australia has allowed women on submarines since 1999. Australian submarines carry a crew of 55 with a six-berth bunkroom for women. Pregnant women are returned to port as soon as possible (W. Mazurek [Wally.Mazurek@dsto.defence.gov.au], e-mail, August 9, 2000 & S. Sharkey [Sarah.Sharkey@defence.gov.au], e-mail, August 10, 2000). None of these three navies operate nuclear submarines. Their patrols are of much shorter duration (generally weeks vs. months) than US Navy submarines and are primarily in coastal waters. The Netherlands, Germany, France and the United Kingdom (UK) do not currently allow women to serve on submarines, citing privacy issues as a significant impediment (B. Mercx [aabg.post@dpkm.navy.mindef.nl], e-mail, September 5, 2000, H. Franz [drfranz2000@hotmail.com], e-mail, June 8, 2000, & J. Panet [panetjj@yahoo.fr], e-mail, August 22, 2000).

The UK parliamentary proceedings state that the government is committed to the idea of maximizing opportunity for women in each of the services provided that combat effectiveness is undiminished. The Ministry of Defence's statutory duty of care under the Health and Safety at Work Act, etc., 1974, states that, when there appears a probability that an occupational exposure could result in some level of risk to a developing fetus that is known or undefined, the duty of care necessitates removing that person from the exposure. An atmospheric contaminant of concern is carbon dioxide (CO<sub>2</sub>). Insufficient data exist to define the maximum safe exposure limits. A woman stationed on a submarine may unknowingly be pregnant for some weeks with the consequent risk of exposure of her unborn child to potentially unsafe levels of contamination. Even if some women were prepared to accept this risk, the Ministry of Defence could not compromise its duty of care by allowing them to do so.<sup>7</sup> The UK has also voiced concern about manning on submarines. The submarine service is a non-voluntary assignment in Britain thus requiring a number of female assignees to maintain 100% manning. This would likely have a detrimental impact on recruiting of females Navy-wide.<sup>8,9</sup>

## **Space Travel**

The National Aeronautics and Space Administration (NASA) launched the first woman astronaut into space in 1983. Medical standards were adapted for women astronauts, with

pregnancy being a disqualifying condition for space travel. Since space missions have been of relatively short duration, NASA did not perform extensive physiologic research on women's health effects of long term exposure to the enclosed atmosphere. Their focus has, however, begun to shift with the challenges presented by long duration exposures in the International Space Station (R. Jennings [rjennings@utmb.edu], e-mail, June 12, 2000 & J. Kerwin [jkerwin@klsiems.jsc.nasa.gov], e-mail, June 13, 2000). Jennings and Santy conducted a literature review concerning reproduction in the space environment looking at both animal and human studies. The effects of microgravity are of such profound impact that atmospheric effects were not commented on in the animal review. The closed environment with subsequent long term exposure to elevated partial pressures of normal atmospheric components as well as the risk of long term exposure to toxins was mentioned in the human review as a concern. They called for beginning animal and human research into all phases of reproduction in space.<sup>10, 11</sup>

## **Literature Review:**

### **Health Care Usage Rates**

Women use the health care system more than men do. Nathanson's 1977 report indicated that for all countries in which data were available, women report more acute illness, make more visits to doctors, are hospitalized more often, miss more days of work, and have more days in bed or restricted from work secondary to illness than do men.<sup>12</sup> Verbrugge, in 1985, reported that women have higher illness rates than men and have more days of illness and disability and a greater incidence of morbidity.<sup>13</sup> The American Medical Association's council on Ethical and Judicial Affairs also noted this trend more recently in a report entitled Gender Disparities in Clinical Decision Making.<sup>14</sup>

In the US Navy, Nice and Hilton looked at 62,671 patient sick call visits from Oct 1988 to Oct 1989 on 20 ships with mixed gender crews. The monthly sick call visit rate for women was 1.79 times that for men. Women attended sick call at a higher rate than men for all illness categories. Obstetrical or gynecological complaints accounted for 25% of the women's visits. The medical evacuation rate was 4/1000 female crewmembers per quarter vs. 3/1000 male crewmembers per quarter.<sup>15</sup> A later study surveyed 628 female and 526 male sailors at the completion of four separate deployments lasting 10-180 days and found that women visited sick call 189/1000 per week vs. 117/1000 per week for men (a ratio of 1.61:1).<sup>16</sup>

In the Perceptions of Wellness and Readiness study, questionnaire data was obtained from 9859 active duty shore based Marine Corps and Navy personnel. The study found that women tended to have higher rates of physical and mental illness, poorer perceptions of their health status and greater health care and medication use than their male counterparts. Women also reported more psychosocial risk factors, such as greater stress, less social support and a lower quality of life than men.<sup>17</sup> Shaffer et al focused on female trainees at Parris Island, SC, Great Lakes, IL and Quantico, VA beginning in April 1995 and ending in June 1996. The study showed a high rate of morbidity, with 85.8% of Officer Candidate School participants, 72.45% of Marine Corps recruits, and 83.4% of Navy recruits visiting sick call at least once during training. The study quoted a related survey of men that showed 61% of male Marine Corps recruits report at least once to sick call for illness or injury.<sup>18</sup>

Similar findings are reported for Britain's Royal Navy. Dorrell reviewed sick bay visits during a 3 month deployment and found that women were seen at a rate 2.6 times that of men, with gynecologic complaints accounting for 21% of their visits.<sup>19</sup>

The data demonstrate a secular trend that can be expected to persist in the submarine environment. Women tend to use health care more frequently than men do with rates ranging from 1.61 to 2.6: 1. The implication is that as the number of women increase onboard a submarine, the demand for an independent duty corpsman's time will also increase. Nice and Hilton demonstrated this for surface ships in a 1990 study, as did Schwerin and Sack in a 1997 study.<sup>15, 20</sup>

### **Specific Diseases of Importance to Submarine Medicine**

The Manual of the Medical Department lists several diseases that are disqualifying for submarine duty, including anemia, asthma, headaches, peptic ulcer disease, orthopedic injuries (generally temporary disqualification), and psychiatric illness.<sup>21</sup> Cardiac disease additionally renders one unfit for both submarine duty and for the Navy in general and will be addressed first.

#### **Cardiac**

Only about 6-10% of myocardial infarctions (MI) occur to individuals under the age of 45. Of these, women account for 5-10%.<sup>22</sup> In the submariner age group (18-50), MI is almost entirely a disease of men. The difference in the rate of MI begins to narrow after menopause. A separate epidemiological study of MI's done over a twenty year span noted that women account for 20% of MI's before age 55 and 55% after age 75.<sup>23</sup> Men have been shown to have a higher blood pressure response to stress, especially in younger age groups. This difference declines with increasing age.<sup>24</sup> The incidence of sudden cardiac death for all age groups is 46% in men and 34% in women. The usual time of occurrence of sudden cardiac death in women lags behind men by 20 years.<sup>25</sup> Data from Bureau of Personnel (BUPERS) Code 42 indicated that cardiovascular disease accounted for 11 submarine force disqualifications in 1996 (unpublished data, 1996).

#### **Anemia**

Anemia is considered disqualifying for radiation health purposes and thus may affect an individual's fitness to serve. Iron deficiency anemia is easily the most commonly diagnosed type of anemia. Looker et al found, in evaluating the records of 24,984 persons age one or older, that 11% of adolescent girls and women of childbearing years were iron deficient, with 5% having iron deficiency anemia vs. less than 1% in adolescent and young adult men.<sup>26</sup> A Navy-based population was found to have lifetime prevalence for anemia of 18.4% for women and 5.9% for men.<sup>17</sup>

## **Asthma**

Asthma disqualifications have been a subject of recent study by the Navy. The rates in the general population are increasing. From 1978 to 1989, asthma mortality doubled.<sup>27</sup> The annual period prevalence in the US Submarine Force is 16/10,000. This represented the loss of 158 trained submariners over a period of 3.5 years.<sup>28</sup> Hourani et al found a point-prevalence for 1994 of 3.4% of Navy women and 1.8% of Navy men.<sup>17</sup> Prior to the onset of puberty, more males are diagnosed with asthma than females.<sup>29</sup> This relationship changes with maturity as more adult women have asthma than adult men. An evaluation of over 33,000 asthma admissions noted a 2:1 male to female rate prior to age 10, an even incidence from age 10-20 and a 3:1 female to male ratio after age 20.<sup>30</sup> Additionally, women report more asthma symptoms, worse quality of life, more use of healthcare and medications and are hospitalized more frequently than men with similar objective measurements of air flow obstruction, suggesting a different response to similar symptoms.<sup>31</sup> This supports the gender differences in health care usage noted by Verbrugge and Schwerin.<sup>13, 32</sup>

## **Headache**

Recurrent severe headache, such as migraine, is also disqualifying for the submarine service. Migraine prevalence is estimated to be 18% for women and 6% for men with the prevalence highest in the 25-55 year old age group.<sup>33-35</sup> Using stricter diagnostic criteria for a Georgia Medicaid population, researchers also noted a 3 times higher prevalence in women but found lower prevalence overall of 3.83% for women and 1.33% for men. The study found a peak prevalence in the fourth and fifth decade of life.<sup>36</sup> A US Navy shipboard population revealed that 36% of women and 19% of men had symptoms consistent with migraine. Physician diagnosed migraine was noted in the medical records of 13% of women and 6% of men.<sup>37</sup> Unpublished medical department data from Commander, Submarine Force, US Atlantic Fleet (SUBLANT) and Commander, Submarine Force, US Pacific Fleet (SUBPAC) indicated that migraine accounted for 56 submarine duty disqualifications from 1995-1997). Hourani et al found a higher migraine prevalence rate differential between men and women. She noted that 10.3% of Navy women and 2.8% of Navy men suffer from migraine, and found in the same study a prevalence of 9.1% in civilian women.<sup>17</sup>

## **Peptic Ulcer Disease**

Men suffer from peptic ulcer disease (PUD) at a rate in one twin study of 6.2% in men to 2.8% in women before age 65 and 14.4% and 6.7% after age 65.<sup>38</sup> Another study quotes a ratio of men to women of 2.1:1.<sup>39</sup> The Perceptions of Wellness and Readiness Study for 1995 indicated a lifetime and point prevalence of PUD that is equal.<sup>17</sup>

## **Gallstones**

Gallstones are two to three times more prevalent in women overall. Between the ages of 20-55, the prevalence for gallstones is 5-20% with the highest figures found for those older than



40. For each given age group, the prevalence for men is at least half of that stated for women.<sup>40</sup> About 30% of patients with gallstones will eventually require cholecystectomy, usually due to biliary colic. This procedure, however, is curative allowing return of an individual to duty. The exact percentage of patients with gallstones that develop attacks of biliary colic or of acute cholecystitis is unknown. Patients may have cholecystitis without the presence of gallstones. The ratio for acute cholecystitis is 3:1 women to men up to age 50.<sup>41</sup>

### **Orthopedic Injuries**

Orthopedic injury rates are significantly higher in women than in men. Army data from airborne troops, basic trainees, and United States Military Academy Cadets consistently shows higher injury rates for women vs. men. The Cadet study found a 2.5 times higher rate for injuries causing at least one missed day of training and a 3.9 times higher rate for injuries requiring hospitalizations for women. Controlling for pre-training fitness levels mitigates this difference to some extent.<sup>42-45</sup> Feuerstein et al looked at 41,720 disability cases in the Army and noted that women had a higher overall disability risk and a higher musculoskeletal disability risk than did men.<sup>46</sup>

Navy and Marine Corps data support the Army findings. Injury rates for males at the Marine Corps Recruit Depot in San Diego and at Parris Island, SC are about 25%. The rates for women trainees at Parris Island (the only training site for Marine Corps women) are 60%.<sup>47</sup> Almeida et al were interested in investigating the possibility of reporting bias in the injury comparison studies. Again, the study subjects were USMC recruits. Reported injuries were documented by record review and overall injuries were examined by end of training examination and questionnaire date. Reported rates were 44% for women and 25.6% for men while exam/questionnaire found injury rates were 53.5% for women and 45.5% for men. The authors indicated that the difference was not statistically significant and felt this indicated a reporting bias.<sup>48</sup> Their study again lends credence to the healthcare usage findings noted previously. A study done at the US Naval Academy focused on anterior cruciate ligament injury from intercollegiate athletics, intramural athletics, and military training. Overall, women had a relative injury risk of 2.44 times that of men. The relative risk for military training alone was much higher at 9.74.<sup>49</sup>

The preponderance of data indicate that women have a higher orthopedic injury risk than men do but that this difference can be improved to some extent by improved physical fitness. The implication for the medical support onboard the submarine is less predictable. Though women are injured at higher rates than men (when participating in the same sports or level of physical training), men tend to participate more frequently in injury-prone sports such as basketball and softball. Manpower losses for orthopedic injuries depend more on individuals and their exposures to risk. The net effect on the ship's medical support will likely be negligible for this category.

### **Osteoporosis**

Another significant aspect of bone health is the risk of osteoporosis. Well known risk factors for osteoporosis include female gender, lack of estrogen, calcium deficiency and vitamin

D deficiency. Lifetime bone mass is dependent on peak bone mass achieved by age 30, which is in turn influenced by sex, genetics, nutrition, and exercise both before and after this age.<sup>50, 51</sup> Postmenopausal women lose bone mass at twice the rate of elderly men and women lose 50% of bone mineral density over a lifetime compared with 35% in men, which helps to account for the fact that 80% of all hip fractures occur in women.<sup>52</sup> Diminished sunlight has been shown in several studies to lead to decreased serum concentrations of vitamin D, increased parathyroid hormone and subsequently increased bone loss both for elderly shut-ins and for those living in northern latitudes with seasonal low light.<sup>53-56</sup> A study in Norway, which has one of the world's highest incidences of osteoporotic hip fracture, showed that the odds ratio for fracture was 5.31 for patients that spent less than 15 minutes per day in sunlight compared to gender and age matched controls. Patients who ingested vitamin D did much better.<sup>57</sup> Dawson-Hughes and colleagues recently showed that spinal bone mineral density decreases in seasons of low sunlight in postmenopausal women but that this difference can be mitigated with vitamin D supplementation.<sup>58</sup>

The submarine environment features relative inactivity, lack of sunlight, and chronic hypercapnia. Inactivity causes bone resorption and increased calcium excretion in the urine. Lack of sun exposure leads to a decrease in vitamin D, which results in bone resorption to maintain serum calcium levels. A United Kingdom study showed that Vitamin D levels fall about 6 ng/ml over a 60-day patrol in the absence of a Vitamin D fortified diet.<sup>59</sup> Vitamin D supplements have proven to be of some benefit. Finally, hypercapnia causes an initial drop in the renal excretion of calcium, which normalizes after 3 weeks. Chronically elevated CO<sub>2</sub> levels (which are less now than when the majority of the CO<sub>2</sub> research was performed; 0.35% compared to .8-1.2%) have been shown to affect calcium metabolism. The net effect on bone mass was undetermined. Hypercapnia tends to cause a renal retention of calcium with data indicating increased resorption of bone leading potentially to elevated serum calcium. Effects on markers of bone turnover were less conclusive. Schaefer et al found, in their work with male subjects, that the urinary excretion of calcium initially fell, then rose to normal, then fell again in a cyclical pattern. The plasma calcium falls in the first three weeks then rises during the 20-40 day period. He suggested that the changes in calcium during adaptation to elevated CO<sub>2</sub> result from the deposition of CO<sub>2</sub> in bone and that bone plays an important role in acid-base regulation during prolonged exposure to elevated CO<sub>2</sub>. All of these effects normalize upon return to the normal environment.<sup>59-62</sup>

More recently in conjunction with work for the International Space Station, Drummer et al tested 4 males in a .7% and a 1.2% CO<sub>2</sub> environment. They found a reduction in bone formation and mild stimulation of bone resorption in parallel with increasing atmospheric levels of CO<sub>2</sub>.<sup>63</sup>

The studies indicate that there are three potential risk factors for osteoporosis on submarines. Lack of sunlight and relative inactivity have a known deleterious effect on bones. The third factor, chronically elevated CO<sub>2</sub> levels, may also have an effect on bone density. Studies have shown that hypercapnia affects different parts of the calcium/phosphorus metabolism cycle but the net effect, especially at current submarine CO<sub>2</sub> levels is unknown. This requires further study. Because women tend to lose significantly more bone mass over their lifetimes than men, and premenopausal bone loss affects post-menopausal risk for osteoporosis,

the effect of these factors on young women needs to be elucidated.<sup>50, 51</sup> The net effect of the submarine environment on the long-term bone health of young premenopausal women needs to be better delineated.

## **Psychiatric issues**

The unique environment and mission of the submarine, combined with the importance of each individual crewmember, makes mental health issues vitally important. The Navy's use of a psychological screening test for incoming submariners attending the Basic Enlisted Submarine School (a screening questionnaire followed by psychiatric interview if indicated)<sup>64</sup> and the Personnel Reliability Program (an ongoing surveillance program for certain crewmembers assigned to missile submarines) attest to this. The Manual of the Medical Department (NAVMED P-117) indicates several psychological conditions that are disqualifying for submarine duty including affective disorders, psychotic disorders, and severe personality disorders. Also disqualifying are suicide gestures or attempts.<sup>21</sup>

Submariners tend to perform well despite the inherent stress of their jobs. In World War II, Duff and Shilling found the psychiatric casualty rate to be .4/1000 man-patrols, a remarkably low rate.<sup>65</sup> Satloff, in 1965, noted an incidence for psychiatric illness of 38/1000 from a population that included operational submarines, new construction and submarines in overhaul. Forty-eight percent of those men diagnosed with a psychiatric disorder were returned to full duty.<sup>66</sup> Other studies that looked at ballistic missile submarine crews in the 1960's revealed rates that varied from 20-50/1000, compared with a psychiatric attrition rate in the rest of the Navy of 71/1000 over the same time period.<sup>67-69</sup>

The psychiatric attrition rate is rising throughout the Navy. The Government Accounting Office report from 1998 indicated that military-wide attrition for personality disorders alone was 7%. This does not take into account numbers lost for all other mental health disorders.<sup>70</sup> This trend has been noted in the submarine force as well. Data from BUPERS Code 42 indicated that there were 232 disqualifications from the submarine force in 1996 for psychological disorders and substance abuse (unpublished data, 1996).

The ensuing section of this paper will explore gender differences in mental health in respect to their potential affect on the operational submarine environment.

## **Overview-Civilian**

An adequate understanding of civilian gender differences in psychiatric illness is critical to understanding trends noted in the US Armed Forces. The Epidemiologic Catchment Area Survey (ECA) from the early 1980's and the National Co-morbidity study (NCS) in the early 1990's are two large, comprehensive attempts to define prevalence of mental illness in the US. The ECA included interviews of 15,571 household and 2290 institutional residents from five US cities.<sup>71, 72</sup> The NCS looked at lifetime and 12 month prevalence for psychiatric disorders in 15-54 year old non-institutionalized civilians. It drew a stratified sample of 8098 subjects from the 48 contiguous US states.<sup>73</sup> Additionally, a study by Mezzich et al looked at 11,292 patients presenting to psychiatric care at a 24-hour psychiatric diagnostic evaluation center in

Pittsburgh.<sup>74</sup> The main findings from all of these studies are remarkably similar. The incidence rates for total mental disorders are essentially equal for males and females (NCS Odds Ratio (OR) .95/1 women to men, ECS OR 1.12/1 W/M). There are marked differences in the types of disorders suffered. Men suffer from substance abuse disorders (OR .22-.50/1 W/M) and antisocial personality disorders (OR .18-.19/1 W/M). Mezzich also noted a significant increased incidence of impulse control disorders (OR .15/1 W/M), psychosexual disorders (OR .17/1 W/M), and schizophrenia (OR .5/1 W/M). Women have a higher incidence of affective disorders including depression and dysthymia (OR 1.53-1.88/1 W/M), anxiety disorders (OR 1.71-2.05/1 W/M) and somatization (OR 1.49-8.56/1 W/M). An interesting caveat in the one month ECA findings is that the highest rates for all disorders was for divorced or separated men and women.<sup>71-74</sup> The sum of findings is that men and women suffer from mental disorders at an equal rate overall with men more likely to experience substance abuse, impulse control, and antisocial personality disorders and women more likely to experience affective, anxiety and somatoform disorders. The question of whether these trends carry over into the military population will be examined next.

### **Overview-Military**

Hourani and Yuan looked at the Navy and Marine Corps in a study patterned after the National Co-morbidity Study. It evaluated a population based, multi-stage, cluster sample of 782 Navy and Marine Corps men and women who were administered a standardized computerized telephone interview. It supported the findings of the ECA and the NCS. There were no significant gender differences for total active or lifetime mental health disorders. Divorced, separated and widowed people had higher rates of mental health disorders. Men were approximately 3 times more likely to suffer from alcohol abuse/dependence (OR .36 W/M) and 4 times more likely to have antisocial personality disorder (OR .24 W/M). Women were 4 times more likely to have Post Traumatic Stress Disorder (PTSD)(OR 4.14 W/M) and approximately 3 times more likely to have a major depressive episode (OR 2.85 W/M). Women also tended to suffer more anxiety and agoraphobia. For all subjects, a lifetime prevalence of psychiatric disorder was 40% with a 1 year rate (active illness) of 21%. Of all people meeting criteria for a psychiatric disorder, only 19% sought treatment. Women sought treatment more readily than men by about 4 to 1.<sup>75</sup> This trend was noted by McCarroll et al in the US Army setting as well. He looked at one Army community health clinic over a 20 month period showed that while women formed 11% of the clinic's catchment area (active duty and dependents), they comprised 17% of the clinic's clients. Women received the diagnoses of anxiety and depression at a significantly higher rate than men while men were diagnosed with substance abuse disorders at a much higher rate than women.<sup>76</sup> Nice and Hilton found in a their study of sick call visits onboard ship that mental health visits made up about 3% of the total sick call visits. Women were seen for this reason at 2.58 times the rate for men. Men were seen for substance abuse screens at 1.98 times the rate for women.<sup>15</sup> The data from the military supports the findings from the studies of civilian populations. The literature from the Persian Gulf War will help to illustrate how the stress of military operations affects psychiatric illness rates.

### **Post Traumatic Stress Disorder**

Mental health research from the Persian Gulf War has taken a detailed look at post-war measures of psychological distress, especially Post Traumatic Stress Disorder (PTSD). In general, Gulf War veterans experienced more hospitalizations for mental disorders than their stateside peers after the war ended. The difference could be accounted for primarily by increased hospitalizations for alcohol abuse, drug abuse, and adjustment disorders.<sup>77</sup> Dlugosz et al studied the post war hospitalization data for the almost 2 million military personnel on active duty during the Gulf War, focusing on whether service in the Persian Gulf was a risk factor for psychiatric hospitalization. There were 30,539 post-war hospitalizations for mental health disorders. Gulf war service was associated with a significant risk for acute stress reactions (may be PTSD but database did not distinguish). The risk for hospitalization for personality disorders or adjustment disorders was less compared to stateside military. Ground war support was associated with greater risk of post-war drug related disorders and men in ground war support were at greater risk for alcohol abuse. They found overall hospitalization risk to be greatest for unmarried persons, women, E1-E4, and lowest educational levels.<sup>78</sup> Sutker et al measured psychological distress in 653 war zone exposed and 259 stateside-duty troops and found a tendency for male minority troops to report more psychological distress. Females, however, did not report greater symptoms of distress or PTSD than their male counterparts.<sup>79</sup> Three separate studies of reserve and national guard troops found little difference in rate of occurrence of PTSD after the war between men and women with the exception of a higher risk for women noted in a unit that had been traumatized by a scud missile attack.<sup>80-82</sup> In a different study, Sutker et al showed a high correlation between combat exposure and development of PTSD symptoms for both sexes.<sup>79</sup>

In contrast to these studies, Wolfe et al noted higher rates for PTSD symptoms and stress related symptomatology among women after the Persian Gulf War.<sup>83</sup> Hines looked at 7 common diagnoses for all of the medical visits for the First Calvary Division during its time in the war-zone. He noted that women were 2 times more likely to be seen for psychiatric problems. He speculated that either this represented a real difference or was simply a function of the location of mental health services. The majority of women were in the support as was the mental health clinic thus increasing ease of access compared to the troops at the front.<sup>84</sup> As noted above, Hourani and Yuan noted a rate of PTSD in women 4 times higher than that in men.<sup>75</sup>

Civilian studies supported the concept that women are at a higher risk for developing PTSD. The ECA data gathered in St. Louis showed a small overall incidence (1%) of PTSD with the rate for women approximately 2.5 times that for men. Physical attack was the precipitating event in women 35% of the time.<sup>85</sup> Breslau and Davis found that in a young adult urban population, women were at greater risk for PTSD even though they were not more likely than men to be exposed to traumatic events. They also found that women constitute 83% of patients with chronic PTSD (greater than one year's duration). The odds ratio for developing chronic PTSD for female gender was 4.43. They also noted that there is a high correlation with other affective illnesses, early separation from parents and antisocial behavior in family.<sup>86</sup> These data indicate that in the civilian setting, women have a higher risk for PTSD. In the military setting, the correlation is not as strong. The data indicate that the risk for PTSD is equal or slightly higher for women than for men in the military. Military training and social support may be a factor in these findings. Further research would help to elucidate the differences seen in these populations.

## **Sexual Abuse History**

A major factor cited by numerous studies as contributing to a woman's risk for developing not only PTSD but other psychiatric maladies is a history of sexual or physical abuse or assault. This factor must be considered in assessing the potential mental health needs of our sailors. Merrill et al surveyed 3,776 male and female Navy recruits for their pre-military history of adult sexual assault, either as victim or perpetrator. Of the women participants, 45.5% had been sexually assaulted (9.4% attempted rape and 36.1% completed rape). The male participants indicated that 14.8% had perpetrated a sexual assault (3.5% attempted rapes and 11.3% completed rapes). Surveys of college students noted 12.1% of women had been the victims of attempted rape and 15.8% of completed rape. The statistics for college males were 3.2% had attempted rape and 4.6% had completed rape of a woman.<sup>87</sup> In a separate study of 1887 female navy recruits, Merrill and colleagues noted a history of rape in 35% and a history of childhood sexual abuse in 57%.<sup>88</sup> The Navy Perceptions of Wellness study confirmed that a significant number of Navy and Marine Corps women had been emotionally, sexually or physically abused before joining the military.<sup>17</sup> Martin, et al looked at 555 male and 573 female US Army soldiers with a self-administered survey and found that 22.6% of women had reported a completed rape while 50.9% of women and 6.7% of men reported attempted assault.<sup>89</sup> Stretch and Durand showed that women experience significantly more sexual trauma prior to entering the military than men do while men experience more non-sexual trauma. These trauma survivors scored lower on measure of psychological health than either civilian counterparts or non-traumatized military members.<sup>90</sup> This combination of a higher number of sexual assault victims combined with a higher number of sexual assault perpetrators is a military-wide problem.

The added complication to be considered for the submarine is that should a sexual assault take place while deployed, neither the victim nor the assailant can be immediately transferred from the boat as they generally can from a surface vessel. Either the submarine's operations would have to be interrupted or the victim and perpetrator will have to coexist on the boat for a period of time.<sup>6,8,9</sup> Experience of sexual harassment in the military is not uncommon. In a sample of female US Army Persian Gulf War veterans with an average time in theater of 3.5 months, 33% reported explicit verbal harassment, 20% reported physical harassment and 8% reported attempted or completed sexual assault.<sup>91</sup>

## **Suicidal Behavior**

Another issue of significant importance for the health of a submarine crew is suicidal behavior. A completed suicide has profoundly negative repercussions on the command. Suicide thoughts, gestures, and attempts require a great deal of medical department time, effort and expertise. Mental disorders (especially depression and substance abuse) are the two most powerful predictors of suicidal behavior. Ninety percent of completed suicides are by persons in one or both of these groups.<sup>92-94</sup> Suicide is the 9<sup>th</sup> leading cause of death in the United States in the general population. In 1994, there were 31,142 suicide deaths, 1.4% of the total number of deaths that year for an age adjusted suicide rate of 11.2/100,000. Nearly 80% of suicide completers are men but the majority of lifetime attempters are women. In 1990 the ratio of male to female suicide rates was 4.2:1. Most studies show female attempts to male attempts to be a ratio of about 3:1. The Epidemiological Catchment Area data showed an overall attempts to

completion ratio of 18:1 (for both sexes). The ratio for women was 59:1 and for men was 8:1.<sup>92-94</sup>

For the military during the period 1980-92, there were 3,178 suicides in all 4 branches representing the third leading cause of mortality for active duty members behind unintentional injury and natural causes. The Marines had the highest rate at 13.65/100,000, followed by the Army 12.38, the Air Force 11.31 and the Navy 11.01. Over 95% of these were by males with a rate ratio of 2.19:1 versus military females. Overall rates for females (5.49/100,000) were slightly less than female civilians. The rates for military males (12.54/100,000) were less than half that of civilian males during the same time period.<sup>95, 96</sup> Hourani et al studied the suicide rates during the years 1990-1996 in the Marine Corps and from 1983-95 in the Navy using, as a comparison group, age matched employed civilians to control for the higher suicide rates among the unemployed. In the Marines, she found fewer suicides than expected overall. Women accounted for only 5 of the 213 suicides that occurred in the time period. While this number was too small to draw valid statistical conclusions, it was a higher rate than expected. They found lower rates among Navy men but somewhat higher rates than civilians among Navy women. The overall numbers again were low and the 20-24 age group accounted for most of the difference.<sup>97, 98</sup>

### **Personality Disorders**

The last area of Navy mental health to address is the Personality Disorders. Though the names and criteria have changed, the problem has been present for many years. Satloff looked at all the psychiatric evaluations for the men in one operational submarine squadron during 1965. Forty percent were for personality disorders representing the largest category by far.<sup>66</sup> Weybrew and Nodden looked at 261 psychiatric disqualifications in the late 1970's. They found the majority (58%) of disqualifications were for neuroses (anxiety and depressive) with the personality disorders next at 27%.<sup>69</sup> Personality Disorders are a significant source of attrition for the Navy in general.<sup>70</sup>

A recent British study found that 24% of a sample of non-military primary care patients had at least one diagnosable personality disorder. The comparison between women and men is more difficult. The different sexes tend to develop different types of personality disorders. Men favor antisocial (approximately 3-5:1) and narcissistic (5:1) personality disorders and women tend to develop histrionic and borderline (approximately 3:1 for both) personality disorders.<sup>99-101</sup> A second difficulty is in the inexact nature of the diagnostic process and the confounding factors of Axis I pathology on the diagnoses. Golomb et al studied a group of depressed outpatient men and women to control for the effect of depression on personality disorder diagnosis. They found that men were diagnosed with antisocial, narcissistic and obsessive compulsive disorder significantly more often than women. When controlling for depression, they found no personality disorder that was more common in women.<sup>102</sup> Alnaes and Torgensen also found that women have less personality disorders overall when the study population is depressed.<sup>103</sup> Gunderson and Hourani recently completed a study of personality disorders in the US Navy and noted findings that confirm the above data. For the period of 1980 to 1992, women had a higher rate of first hospitalization for personality disorder overall than men (study was, however, not controlled for affective illness.) Interestingly, shipboard men (combat and support ships) were 2-

3 times more likely than shipboard women (support ships only) to have required a first hospitalization for personality disorder. The submarine service had the lowest risk for personality disorder diagnosis lending additional credence to the benefit of the SUBSCHOOL psychological screening test.<sup>104</sup> Taken together, the data do not indicate a clear gender effect in this area.

### Mental Health Summary

In both the civilian and military communities, the amount of mental illness among men and women is approximately equal with men suffering from antisocial personality disorders and substance abuse problems and women suffering from affective, anxiety, and somatoform disorders. Women do tend however to seek treatment more readily. PTSD probably has a higher incidence in women though there is disagreement on this. Women attempt suicide more frequently but men complete suicide more frequently. Women, especially military women tend to have been victimized by sexual abuse or assault at a higher frequency. And finally, the data on personality disorders is not revealing. (Table 1)

**Table 1.** Mental Health Gender Comparison Summary

Mental Health Gender Comparison Summary*			
Variable	Men	Women	Reference
Overview	+++	+++	71-76
Antisocial Personality Disorder	+++++	+	71-76
Substance Abuse	+++++	+	15, 71-76
Depression	+	+++	71-76
Anxiety Disorder	+	+++	71-76
Somatoform Disorder	+	++++	71-76
Pursuit of Care	+	+++	15, 75, 76
PTSD	++	+++	75, 77-86
Sexual Abuse	+	+++	17, 87-91
Suicide Attempts	+	++++	92-98
Suicide Completions	++++	+	92-98
Personality Disorder's	++	++	66, 69, 70, 99-104
*Relative incidence based on compilation of data available to author			

Mental health issues will continue to be relevant to the submarine force. Women have different mental health issues than men. However, the frequency overall appears from the literature to be approximately equal between the sexes. Taken together, the increased tendency to seek treatment, the increased incidence of PTSD, the increased rate of suicide attempts and the type of disorders women suffer from (depression and anxiety) suggest that the medical department will be spending more time in the evaluation and treatment of mental health issues. Additionally, the effect of the history of sexual abuse on women, specifically on the potential for



PTSD and the difficulties of living in close quarters with men and in light of the frequency of sexual harassment issues in the military will require careful consideration. Modifying the current psychiatric screen for use with female submariners could mitigate many of the concerns for their mental health. This would screen out sailors with histories of depression, suicide attempts, and anxiety disorders.

## **Women's health**

The focus of this section on women's health care needs shifts away from gender differences to one of magnitude. The goal is to explore obstetrical and gynecological needs in light of their potential effect on the submarine medical department and on submarine-assigned women. This review will now address military and civilian data and examine the obstetrical-gynecological experience of mixed gender ship crews and the Persian Gulf War, followed by a discussion of fetal development and a summary of medical care capability on a submarine.

### **General gynecological needs**

The senior medical officer on the USS DWIGHT D. EISENHOWER summarized the medical experience of the first mixed gender cruise of a combat vessel which occurred October 1994-April 1995. The ship deployed with 415 female crewmembers. The carrier supported the Haiti intervention, was in the Middle East when Iraq sent troops to the Kuwait border, and flew No-Fly zone patrols over Bosnia. There were 15 pregnancies, 12 of which were thought to have been present prior to deployment. The other three were thought to have occurred on shore leave. It was a mishap-free cruise and was considered a success.<sup>105</sup> He pointed out that there were no insurmountable medical issues. No women were medically evacuated (MEDEVAC'd) for gynecological conditions other than pregnancy. Pregnancy was considered, by the medical and line leadership, to be incompatible with service on a warship.<sup>106</sup>

In 1995, Means-Markwell et al did post-deployment surveys of 628 female and 526 male members of 4 ships. They found that women visit sick call at a rate of 1.6 times the rate of men, often for routine gynecologic care. The most common gynecological visits were requests for contraceptive pills, vaginal discharge, menstrual cramps or abnormalities, and pregnancy checks.<sup>16</sup> A 1990 study by Hughey revealed 2.7 gynecological visits per female crewmember per year (excludes routine prenatal care), 8% of which required consultation to a specialist.<sup>107</sup> Nice and Hilton surveyed sick call visits on 23 ships in 1988-89 and found a gynecological visit rate of 1.2 per female crewmember per year. The most frequent non-pregnancy related complaints were urinary tract infections, premenstrual syndrome, dysmenorrhea, vaginitis, and dysfunctional uterine bleeding.<sup>15</sup>

Literature from the Persian Gulf War provides a glimpse at gynecological needs in a combat environment. Gynecological problems accounted for 20-25% of women's visits, the most common of which were dysfunctional uterine bleeding or amenorrhea, contraceptive issues, pregnancy or ruling out pregnancy, vaginitis and pelvic or lower abdominal pain. About 3% of cases needed referral to a gynecologist. Gynecological indications including ectopic pregnancy, miscarriage, pelvic pain and pelvic inflammatory disease among others accounted for 1-1.5% of hospital admissions. Pregnancy was the most common reason for medical evacuation out of

theater. Abnormal pap smears were an additional source of frustration as definitive evaluation required MEDEVAC for colposcopy, which was not available in the field. The authors agreed that consistent pre-deployment screening, proper equipment and examination facilities were needed. One author felt that the health care needs of women can be managed for the most part by a competent broadly trained practitioner. Another indicated that it was unlikely that deployed women pose a significant health care burden attributable solely to their gynecological needs. Yet another indicated that most of the conditions were easily handled as outpatient therapy and that over 50% of the cases were managed with one or more of six medications from the non-steroidal anti-inflammatory drug, oral contraceptive pill, and antibiotic categories. An additional recommendation was that referral sites should be able to provide gynecological consultants along with the equipment and resources needed to manage pregnancy complications, pelvic pain, and abnormal cervical cytology.<sup>108-112</sup>

Other studies have described specific gynecological disorders in the military and civilian population and are germane. Pierce et al administered a self-reported survey to 638 women on active duty during the Persian Gulf War. They found premenstrual syndrome rates of 23%.<sup>113</sup> In a large survey of active duty women incorporating all branches of service, Hourani et al found a prevalence of PMS symptoms of 69%.<sup>114</sup> At the United States Military Academy, a study done on new female cadets showed that menstrual or premenstrual symptoms interfered with physical activities 61.4% of the time, academic activities 45.7% of the time and military activities 47.0% of the time.<sup>115</sup> A British survey found the annual prevalence of pelvic pain in the primary care setting to be 38.3 per 1000.<sup>116</sup> A study of US women in the age group 18-50 found a prevalence of chronic pelvic pain of 14.7%.<sup>117</sup>

Fischer and Berg found a prevalence of occasional urinary incontinence of 26.3% in female aircrew in the US Air Force. This finding was similar to the general population and increased with increasing age and parity.<sup>118</sup> Davis et al found prevalence in female Army troops of urinary incontinence of 31%.<sup>119</sup>

The rate of cervical disease among female sailors is high. In 1990, on the USS FRANK CABLE, 20% of the female crew required treatment for cervical disease. A study on recruits showed a rising rate of disease with 8% affected in 1993, 25% in 1995 and 28.8% in 1996.<sup>120, 121</sup> A history of sexually transmitted disease is common for both sexes in the Navy. The rate for pelvic inflammatory disease from self reported data in 1988 was 10.1/1000 women years for white women and 16.5/1000 women years for non-white women.<sup>122</sup>

These studies indicate that the six most common categories of gynecological problems in combat and on ships are menstrual disorders, dysfunctional uterine bleeding, sexually transmitted diseases, pelvic pain, cervical disease and incontinence. Submarine IDC training should focus on these conditions. Good female health management algorithms and a revised authorized medical allowance list (AMAL) will allow the corpsman to manage most cases of the first three conditions. The submarine IDC must have a good understanding of the last three, which often require referral, and know the urgency with which these referrals must be made. A review of the current training curriculum at Naval Undersea Medical Institute as well as evaluating the management algorithms from the surface fleet is recommended.

## Pregnancy and Early pregnancy complications

Pregnancy is a concern for the US Navy in general and for the submarine force in particular for at least three reasons: the effect on the submarine from the unplanned loss of a pregnant service member, the health of the mother, and the health of her unborn child. Each of these areas will be examined in turn.

### 1. Pregnancy and the submarine

Unplanned personnel losses severely influence submarine crews and mission effectiveness. A loss of even one crewmember increases the burden on the remainder of the crew considerably. OPNAVINST6000.1A, the Navy's policy on the management of pregnant service members allows women to stay on board ship until their 20<sup>th</sup> week. They must be reassigned if environmental hazards to the pregnancy exist in their workspace and they cannot deploy if medical evacuation time exceeds six hours.<sup>123</sup> In practice, this generally results in transfers from a ship much earlier than 20 weeks. The practice for deployed combat ships or troops has been immediate medical evacuation upon verification of pregnancy.<sup>106, 111, 112</sup>

In 1996, the pregnancy rate for all women age 20-24 was 183/1,000.<sup>124</sup> The pregnancy rate for all women on ships in the Pacific Fleet in 1992 was 117/1000. This rate varied according to ship type. From 1990-96 for three submarine tenders, the rate was 20% of the female crew per year.<sup>120</sup> A single tender was noted to have a rate of 18% per year in 1995, which was down from a rate of 32% found in 1990.<sup>125</sup> The initial deployment of the USS DWIGHT D. EISENHOWER with women resulted in a pregnancy rate of 6.7% per year.<sup>105, 106</sup> The estimate for smaller combat vessels has been less than 1% per year.<sup>126</sup> Garland looked at data from 53 ships from 1994 to 1996 and found a pregnancy rate that varied from 0% on LHA and LHDs to 27% on a submarine tender with an overall average of 19% per year.<sup>127</sup> In the Persian Gulf War, the most common reason for medical evacuation was pregnancy.<sup>112</sup> Data from the USS EMORY S. LAND from 1994-97 indicated that 58% of pregnancies occurred in unmarried women, 81% were in pay grades E1-E4, and 70% were unplanned.<sup>120</sup> (Table 2)

**Table 2.** Summary of Studies with Estimated Navy Pregnancy Rates.

Summary of Studies with Estimated Navy Pregnancy Rates			
Dates	Data Source	Pregnancy Rates*	Reference
1996	US pop. Age 20-24	183	<sup>124</sup>
1992	Shipboard Women, Us Pacific Fleet	117	<sup>120</sup>
1990-1996	Three Submarine tenders	200	<sup>120</sup>
1995	Submarine Tender	180	<sup>125</sup>
1990	Submarine Tender	320	<sup>125</sup>
1994	USS DD EISENHOWER	67	<sup>105, 106</sup>
1994-1996	53 Ships	190 (avg)	<sup>128</sup>
	-LHA/LPD	0	<sup>128</sup>
	-Sub Tender	320	<sup>128</sup>
*all rates converted to pregnancies per 1000 women per year for comparison			

Garland found in 1995-96 for 61 ships that the unplanned pregnancy rate was 58% and the unmarried pregnancy rate was 34%.<sup>128</sup> Navy wide, BUPERS estimates that 69% of pregnancies are unplanned for the E1-E4.<sup>120</sup> The Government Accounting Office report stated that, for women in 1993, the principle reason for separation before completion of initial enlistment was pregnancy, which accounted for 26.3% of female attrition.<sup>70</sup> Taken as a whole, this data presents a significant readiness consequence for the submarine force. There are, however, indications that these statistics would not necessarily be present on submarines. There seems to be a motivational and maturity factor that influences pregnancy rates that could carry over into a volunteer submarine force. This may also be mitigated by the ages of women assigned to submarines. Presumably, more senior and higher-ranking female personnel would, according to the data presented, result in fewer unplanned losses.

## **2. Pregnancy and the mother's health**

A woman may not be aware of her pregnancy until several months after conception. During this time, the two most significant threats to her health are ectopic pregnancy and spontaneous abortion. Ectopic pregnancy is the second most common cause for maternal death.<sup>129</sup> Spontaneous abortion occurs once in every six pregnancies and threatened abortion occurs in one of every three pregnancies. Management of these conditions requires sensitive laboratory tests and frequently pelvic ultrasound examination. Surgery is generally necessary with ectopic pregnancies and is usually required on an emergency basis. Surgery can also be indicated in spontaneous abortion when bleeding is uncontrolled.<sup>130</sup> Ectopic pregnancy occurrence is generally thought to be 1 out of every 100 pregnancies. There are some differences when varying populations are surveyed. Nederlof et al looked at ectopic pregnancies in the US in 1987 and found that 1.7% of all pregnancies (1/60) were affected and that 12% of maternal deaths could be blamed on this condition. The author also noted that 80% of the ectopic pregnancies that ruptured did so between 4-8 weeks after the last menstrual period.<sup>131</sup> Birdsong looked at the ectopic pregnancies that occurred in an Air Force medical center in Germany from 1981-85. He found a rate of 1/28 pregnancies for Army and Air Force enlisted women compared to a rate of 1/117 for Army and Air Force dependent wives. He noted the large discrepancy between these two populations but was unable to explain the findings.<sup>132</sup> Garland et al examined pregnancy outcomes for 3,853 Navy women in 1995-96 stationed on 61 ships and found a 10% rate of spontaneous abortion and 1.4% rate of ectopic pregnancy.<sup>128</sup> Nice examined 33,130 hospitalized adverse pregnancy outcomes for 25,763 Navy enlisted women between 1982 and 1992. He found a rate of 7.3% for spontaneous abortion and 2.7% for ectopic pregnancy.<sup>133</sup> Dr. Schlichting recently analyzed raw data from the Defense Medical Surveillance System (DMSS), a military wide hospitalization data base and found an ectopic pregnancy rate in 1999 of 1.24/1000 person years for enlisted US Navy women and 1.17/1000 person years for officers (personal communication, 2001). Lyon's review of Desert Storm literature revealed 4 hospital admissions for ectopic or suspected ectopic pregnancy and 3 hospital admissions for threatened miscarriage.<sup>111</sup> Very few women in the Gulf War required hospitalization or surgery for ectopic pregnancy or spontaneous abortion.<sup>108-110, 112</sup>

The minimal occurrence of these early pregnancy complications in the operational setting is related to the policy of medical evacuation of pregnant personnel upon diagnosis, thus avoiding the most dangerous period. Garland et al modeled an incidence of spontaneous abortion and ectopic pregnancy for deployed ships should women remain on board until their 20<sup>th</sup> week of pregnancy. The data used came from three sources: the NHRC hospitalized pregnancy study, the NHRC women aboard ship study and an enlisted personnel survey. The time at sea for the ships involved was computed as well. The overall pregnancy rate was 19 per 100 women-years based on the female complement assigned to ships at the study time. Given the above parameters, predicted incidence is nine ectopic pregnancies and 40 spontaneous abortions per year during deployments.<sup>134</sup> Modeling has weaknesses in that the results are based on assumptions used, but nonetheless is useful in medical planning. An example of this kind of modeling as calculated by Schlichting in 2001, based on DMSS appears in Table 3 below.

**Table 3.** Estimated Ectopic Pregnancy Risk.

Variable	Rate of Ectopic pregnancy in 1999 from DMSS	Calculated person years	Calculated ectopic rate
Ectopic Pregnancy Risk-Enlisted	1.24/1000 person years	340 person years <sup>1</sup>	0.4 per year or 1 Ectopic pregnancy every 2 years
Ectopic Pregnancy Risk-Officers	1.17/1000 person years	68 person years <sup>2</sup>	0.08 per year or 1 Ectopic pregnancy every 10 years
<sup>1</sup> Assume 20 female enlisted members for each of 17 TRIDENT submarines spending average of 6 months at sea			
<sup>2</sup> Assume 4 female officers for each of 17 TRIDENT submarines spending average of 6 months at sea			

Even one ectopic pregnancy on board a deployed submarine will be exceedingly difficult to manage. Any complaint of abdominal pain or non-menstrual vaginal bleeding by a female crewmember should prompt a consideration of ectopic pregnancy and a pregnancy test. A positive could well indicate a spontaneous abortion with uncontrolled bleeding or an ectopic pregnancy, both of which will require immediate MEDEVAC. Further diagnostic testing and treatment will not be available on the submarine and there are no temporizing procedures that will allow these conditions to be managed on board. This will affect the mission of the submarine. Additionally, a submarine MEDEVAC requires transit to port, or transfer to another ship while at sea, or helicopter transport. With the exception of MEDEVAC at pier-side, the other methods incur considerably greater risk than MEDEVAC from a surface vessel due to submarine design.

### 3. Fetal development

The effects of living in the closed environment of a submarine for long periods of time have been a medical research concern since submarines have been in existence. It assumed top priority when submarines became nuclear powered with self-maintained atmospheres. The Naval Submarine Medical Research Laboratory (NSMRL) began research on the effects of closed atmospheres in the 1950s and maintains the Submarine Atmosphere Health Assessment

Program (SAHAP). The Navy has developed risk assessment profiles for almost 200 chemicals in the submarine environment for the purpose of defining maximal permissible concentrations (MPCs). Approximately 30 of these are routinely monitored on board.<sup>135</sup> These assessments did not consider women crewmembers and their reproductive health risks. The possibility of a woman being pregnant while deployed cannot be dismissed. She may deploy prior to recognition of pregnancy, she may conceive while deployed either in port or underway, or she may intentionally hide the pregnancy for professional, financial, or other reasons. The effects of the submarine environment on the developing fetus are as yet unknown.

The Batelle and Research Triangle Institute reports on submarine atmospheres and ongoing sampling by SAHAP at NSMRL have shown that submarine atmospheres contain compounds such as toluene, ozone, carbon monoxide, carbon dioxide, and others, all of which may have adverse reproductive effects.<sup>136, 137</sup> The Royal Navy's Institute of Naval Medicine (INM) in Portsmouth, UK, after an extensive literary review and consultation with experts, concluded that there were 29 contaminants in the submarine atmosphere that required additional study to define MPC's in regard to reproductive health and fetal development.<sup>138</sup> There is evidence that occupational exposure to solvents, particularly organic solvents, increases the risk of spontaneous abortion.<sup>139, 140</sup> Other shipboard environmental hazards include heat, which has been found to increase the risk of fetal malformation (neural tube defects and others)<sup>141-143</sup>, noise exposure, which has been found to increase the risk of spontaneous abortion, threatened abortion, premature labor, pregnancy induced hypertension, fetal death and low birth weight infants<sup>144</sup>, and low frequency whole body vibration in the 1-10 hz range, which has been shown to be a risk for spontaneous abortion and stillbirth.<sup>145</sup> Additionally, physical stressors, such as shift work, long hours standing, and lifting have consistently been shown to increase the risk for spontaneous abortion and pre-term birth.<sup>146</sup> Radiation exposure is a known risk on submarines but is considered safe provided strict adherence to current exposure guidelines.<sup>123</sup>

The above risk factors have resulted in current Navy policy regarding pregnancy and duty onboard ships, outlined in OPNAVINST 6000.1A, 1989. This instruction provides for reassignment of the pregnant servicewoman if her environment is judged by the cognizant occupational health professional or health care provider to contain environmental hazards or toxins. The instruction contains a list of known toxins. She is exempt from regular physical training with her unit, the physical readiness test, prolonged standing, routine immunizations, and participation in weapons training. As her pregnancy proceeds, she is limited to a 40-hour week though she can still be assigned to night shifts. She is also not allowed to deploy with the ship if her transit time to emergency health care is greater than 6 hours. The pregnant servicewoman is transferred from the ship at 20 weeks.<sup>123</sup>

The U.S. Supreme Court in *Johnson Controls vs. United Auto Workers* ruled fetal protection policies illegal in 1991. Therefore, the work place must maintain policies equally protective to reproductive health of men and women. The cited case involved the employer, Johnson Controls, removing women of child-bearing potential from work in lead battery manufacture because of the known fetal development risks of lead exposure. The Supreme Court stated that this was discriminatory in that fertile men but not fertile women were given the choice as to whether they wished to risk their reproductive health on the job. The court stated that fertility issues must be examined for both sexes and that women cannot be excluded simply

because of their ability to become pregnant. Protection of the health of the unborn child is the immediate and direct responsibility of the prospective parents.<sup>147</sup> The US Navy, however, as noted in OPNAVINST 6000.1A, has adopted a more conservative fetal health protection policy.<sup>123</sup>

A review of one chemical contaminant present in the submarine atmosphere illustrates the complexity of the problem. Atmospheric sampling has shown that levels of carbon dioxide (CO<sub>2</sub>) in ballistic missile and fast attack submarines averaged 0.35%-0.41%. This is approximately 10 times normal ambient air levels (.03%). According to data collected at NSMRL in 1980, the highest levels recorded in both types of submarines were between 0.5% and 1.0% (unpublished data, 1980). Carbon dioxide in the submarine atmosphere is produced as a by-product of human respiration, cooking, smoking, and CO/H<sub>2</sub> burners. Previous studies have concluded that current levels are safe for males.<sup>62</sup> Studies conducted on small animals have produced the following findings:

1. The offspring of 435 rats exposed to 6% CO<sub>2</sub> for a single gestational day demonstrated a cardiac malformation rate of 24.8% compared with 6.8% in control animals.<sup>148</sup>
2. The offspring of rabbits exposed to 10-13% CO<sub>2</sub> for 4-10 hours during day 2-12 of their pregnancy demonstrated an increased incidence of congenital hypoplasia of the vertebral column.<sup>149</sup>
3. Respiratory acidosis in pregnant mice induced by breathing 15% CO<sub>2</sub>, is associated with limb malformation in their offspring.<sup>150, 151</sup>

A literature search for fetal effects of elevated CO<sub>2</sub> in occupational settings such as space flight missions, diving, mining, power generation, dry ice, welding, and beverage industries was unrevealing.<sup>152</sup> The literature regarding pregnant patients with medical conditions that result in CO<sub>2</sub> retention, such as alpha-1-antitrypsin deficiency, chronic obstructive pulmonary disease (COPD), cystic fibrosis, asthma, sleep apnea and other hypopneic syndromes, and congenital cyanotic heart disease, was also not helpful.<sup>153</sup> The only firm conclusion is that CO<sub>2</sub> causes fetal defects at certain elevated levels in mammals. The minimal level at which this occurs is unknown. To determine the MPC for women will require extensive further animal research. The Royal Navy has opted to not allow women to serve on their submarines because of the unknown effects of submarine atmospheric constituents such as elevated CO<sub>2</sub>. United Kingdom law states that if, after proper risk assessment, and in spite of all reasonably practicable measures having been taken, there remains a risk to the health of a woman or to the fetus of a pregnant woman because of her employment, she should be excluded from that working environment.<sup>138</sup>

The submarine atmosphere, containing a chronically elevated level of CO<sub>2</sub> and other contaminants, and submarine environmental factors such as noise and vibration levels, present currently unknown risks to the fetus. Reassurance, therefore, cannot be given to the reproductive age crewmember should she be pregnant while deployed. Research is necessary in this area to further elucidate this question. The Toxicological Detachment of the Naval Health Research Center (NHRC TOXDET) indicated in a brief proposal, that the necessary multigenerational reproductive animal testing to establish maximal permissible concentrations for CO<sub>2</sub> and one or

two specific contaminants such as toluene or acrolein would require 5 years and cost approximately 3.5 to 5 million dollars.<sup>135</sup>

### **Submarine Medical Support**

Medical support and facilities on board submarines are limited. The attack submarine Independent Duty Corpsman (IDC) works in a cramped space (containing the three-inch ordnance launcher). There is no dedicated examination table. Exams requiring the patient to lie down are conducted on the deck or on a mess table. The adaptability of these limited facilities for women's health care needs to be addressed. Makeshift gynecological exam tables can be fashioned with a minimum of equipment for field exams. Detailed consideration regarding privacy, equipment and space is needed. TRIDENT class submarines have a larger medical office with an exam table. However, the table is surrounded on three sides with bulkheads and cannot be used for gynecologic exams.

Submarine IDCs are trained in all aspects of medical care at the Naval Undersea Medical Institute (NUMI) in a rigorous one-year course of study prior to being assigned to a submarine. NUMI reports that submarine IDCs receive 48 hours of didactic training and 6 hours of laboratory training with live models at Yale University Medical Center for male and female reproductive health care. IDC students study numerous male and female genitourinary disease scenarios.<sup>154</sup> After leaving NUMI, submarine IDCs generally care solely for adult men and tend to feel less confident providing healthcare to women. In a recent study, IDCs reported significantly less confidence with OB-GYN training and care-giving onboard ships than medical officers.<sup>20</sup>

The most significant differences between IDC-supported surface ships and submarines are found in medical communications and medical evacuations. Submarine medical communications are limited to carefully formatted messages sent only when absolutely necessary. The process begins with an IDC's succinct description of the patient's condition to which the shore based medical officer consultant replies with clarifying questions and initial medical advice. Messages must be exchanged in this fashion until the physician can accurately advise the corpsman on the necessity of a MEDEVAC. Surface ships generally remain in constant radio contact with the shore and with other ships in the battle group allowing their corpsman the opportunity to actively discuss patient questions with a medical officer. The process of transferring an ill or injured patient to a higher level of medical care is also more difficult from the submarine. Submarine MEDEVACS at sea are dangerous for the patient and crew. They also require the submarine to surface, risking detection. A safer but more mission comprising option is patient transfer at the nearest port.

Nice looked at medical communication and MEDEVACs from ships at sea in 1983. He noted that significantly more MEDEVACs were initiated by ships with independent duty corpsmen only compared to those with a medical officer. The mean was 3.5 per 1000 patient visits versus 1.5 per 1000 patient visits for ships with physicians on board. Over 80% of the medical evacuations were preceded by a medical communication.<sup>155</sup>



## **Conclusion**

This review has focused on the medical implications for women on submarines in two ways; effects on the submarine (its mission and its medical department) and effects on the individual woman's health (including her offspring). Before summarizing the findings, it is important to consider the limitations of this type of data. The populations studied in the available literature may not be easily compared to the population of interest. The population of interest does not yet exist, rendering definitive conclusions about this population unreachable. Because of these facts, the conclusion will focus mainly on elucidating areas that require further study.

### **Implications affecting the Submarine**

Women use healthcare at a rate 1.5 to 2.5 times higher than men. It can be expected that as the number of women increase on a submarine, the demand for an IDCs time will also increase. This trend will require study to assess the potential operational outcome.

Women have higher rates of migraines, anemia, asthma, gallbladder disease, and urinary tract infections. Men have higher rates of heart disease and peptic ulcer disease. Manpower losses due to these submarine and radiation health disqualifying conditions will likely increase. Along with the losses, there will be a significant increase in the generation of waiver requests. The population of women selected to serve onboard a submarine will need study. The closest analog population currently is the crew on small surface ships that are served with independent duty corpsmen. There is some suggestion that these women are healthier and more highly motivated than many of the populations studied in the surface Navy to date. The data are not currently available to compare this population.

Women have a higher rate of orthopedic injury than men but this difference can be mitigated to some extent by improved physical fitness. The implication for the medical support onboard the submarine is more difficult to predict. Manpower losses for orthopedic injuries depend more on individuals and their exposures to risk. Though women are injured at higher rates than men (for similar activities), men tend to participate more frequently in injury prone sports. Thus the net effect on the ship's medical support will likely be negligible.

Men and women suffer from an approximately equal overall incidence of psychiatric disease. Men suffer more from antisocial personality disorders and substance abuse problems while women suffer more frequently from affective, anxiety and somatoform disorders. Women do tend, however, to seek treatment more readily. Though there is disagreement, PTSD probably has a higher incidence in women. Women attempt suicide more frequently but men complete suicide more frequently. Taken together, the increased tendency to seek treatment, the increased incidence of PTSD, the increased rate of suicide attempts and the type of disorders women suffer from suggest that the medical department will be spending more time in the evaluation and treatment of mental health issues if women are assigned to submarines. An additional concern is the high rate of pre-service sexual abuse or assault suffered by military women and how this would manifest itself in the closed submarine environment. Again, the population of interest has not yet been created. Research is also necessary to modify the submarine psychiatric screen for

use in women. Potentially, effective screening could lower the rate of psychiatric difficulties in female submariners as well as it has in male submariners.

General gynecological complaints include menstrual disorders, dysfunctional uterine bleeding, pelvic pain, sexually transmitted diseases, cervical disease and incontinence. Effective submarine medical support will require training and facilities to deliver care for these diagnoses. The IDC and UMO curricula at NUMI will need review to include these common areas. The development and use of appropriate gynecological management algorithms, including diagnosis recognition and referral by the IDC, will be needed as well. Authorized Medical Allowance Lists also need review and modification. IDCs have been providing women's healthcare in the surface fleet since 1994 so many of these issues have been evaluated. The unique difficulties of the submarine will need to be incorporated into current Navy practices. These include the increased difficulty of communication with shore-based medical advisors and the increased difficulty of medical evacuation.

Finally, manpower loss because of pregnancy requires attention. Navy wide, pregnancy losses are significant. Statistics for women on submarines may be similar to the findings on the small combat vessels. The effect of a strongly motivated, more mature, volunteer population of females will probably reduce this type of loss.

#### **Implications affecting the Woman's health.**

Studies indicate three potential risk factors for osteoporosis on submarines. Lack of sunlight, relative inactivity, and chronically elevated CO<sub>2</sub> levels. Because of a woman's natural rate of bone loss throughout her life, she may be at increased risk for osteoporosis due to service in submarines. The complex interactions of these risk factors in a young premenopausal population of women requires further research.

The risks of ectopic pregnancy and spontaneous abortion need further attention. The previously mentioned submarine communication and MEDEVAC problems require additional consideration and planning. Rigorous pre-deployment pregnancy screening will likely minimize underway fetal exposure but cannot guarantee its absence. Reasons include early undetected pregnancy, conception while deployed and intentional pregnancy concealment. Modeling, similar to that done by Garland at NHRC regarding MEDEVACS and pregnancy complications in the surface fleet should be accomplished for the submarine population as well. Female volunteers for submarine duty may have to accept a level of risk for pregnancy complications.

Risks to the developing fetus are at present unknown. Reassurance cannot be given that a developing fetus would not be harmed by the nuclear submarine environment. Extensive animal research will be needed as outlined by the Toxicological Detachment of NHRC above. This research will need to evaluate fertility and fetal development effects of carbon dioxide at a minimum, in multi-year, multi-generational studies.

## Research Requirement Recommendations

- a. Submarine atmosphere effects study.  
Evaluation of the potentially toxic effects of submarine atmosphere contaminants and elevated carbon dioxide levels using multigenerational studies.
- b. Bone health study.  
Animal and human research on bone health investigating the impact of elevated carbon dioxide, the absence of sunlight, and the relative inactivity of the submarine environment.
- c. Epidemiological studies.
  - Initiation of an institutionalized submarine health surveillance program.
  - An evaluation of submariner morbidity and modeling studies on women's medical care needs to determine the impact of increased health care utilization, risk of ectopic pregnancy, spontaneous abortion, and pregnancy on the submarine service.
  - Male submariner reproductive health study.
- d. Medical care for women on submarines assessment.  
An assessment of additional medical supplies and equipment, fixture modifications, medical procedures planning, and need for an additional corpsman to ensure adequate medical care for women serving onboard submarines.
- e. Submarine screening test modification.  
Research on modification and application of submarine duty psychological screen to females.
- f. Training assessment.  
Review and assessment of submarine IDC training curriculum and development of women's health management algorithms.

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