Physical Fitness and Occupational Performance of Women in the U.S. Army

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The majority of jobs available to personnel entering the U.S. military services are physically demanding. Soldiers must maintain high levels of physical fitness to optimally perform their duties. High fitness levels are of particular importance to women in the military. Only strong, physically competent women will be fully successful in performing the physically demanding tasks of many occupational specialties. This paper describes the research that has been conducted to compare the physical fitness, physical training, and occupational performance of women and men in the U.S. Army.

Keywords: Physical fitness; Muscle strength; Aerobic capacity; Training; Women

Women have served the U.S. Army in a formally recognized capacity since the Nursing Corps was created in 1901. In 1942, during World War II, the Women's Army Auxiliary Corps was created to fill clerical positions with women, thus freeing men for the combat arms. In 1943 the Women's Army Corps was created and gradually established a permanent role for women in the army. To promote equality and more fully integrate women, the Women's Army Corps was disbanded in 1978, and women became part of the regular U.S. Army (Morden, 1989). Since 1978 women have been assigned to nontraditional, physically demanding jobs in increasing numbers (Morden, 1989) and currently make up 11% of U.S. Army personnel (Herres, Clarke, Cockerham, et al., 1992).

Through 1992 U.S. law has excluded women from serving in direct-combat positions, which comprise about 10% of all army occupational specialties (Herres, Clarke, Cockerham, et al., 1992). As directed by former Secretary of Defense, Les Aspin, these laws are being modified to include women in more military occupations, including direct-combat positions. Women will soon be flying combat aircraft, including fighter jets and attack helicopters, and will probably be-

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Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on the use of volunteers in research.

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gin serving on the U.S. Navy's combat vessels. The U.S. Army is considering changing the policy that bars women from the fields of rocket artillery, cannon artillery, air defense artillery, and combat engineering—all physically demanding jobs (Council and Ostendorf, 1993). Of the non-direct combat occupations that have traditionally been open to women, about one-third have heavy or very heavy physical demands requiring the soldier to lift, carry, push, or pull loads in excess of 40 kg (Myers, Gebhardt, Crump, et al., 1984). In addition to the tasks specific to an occupation, all soldiers perform common soldiering tasks during times of military conflict. The common soldiering tasks include setting up tents and camouflage nets and manually moving equipment and supplies. Therefore, while soldiers may be assigned to an occupation designated as having light physical demands, they must also be capable of performing the physically demanding common soldiering tasks. The purpose of this paper is to describe research that has examined the physical fitness and performance of women in the military and the factors that contribute to gender differences in these areas.

COMPONENTS OF PHYSICAL FITNESS: COMPARISON OF MEN AND WOMEN

Physical fitness, or the capacity to perform physical work, can be thought of as having three components: muscular strength, muscular endurance, and cardiopulmonary fitness. Body composition and size are not generally considered to be fitness components but can have a significant impact on job performance. A large data base describing relationships between physical fitness and body composition has been compiled by the U.S. Army for both men and women.

Body Composition

The body is composed of several different types of tissue serving different functions. For the purposes of this paper, body composition is defined as the relative proportion of nonfat and fat tissue mass. Body fat is expressed as a percentage of body weight (percent body fat) or as a mass (body fat in kg). Fat-free tissue includes skeletal and smooth muscle mass, connective and structural tissue (Marriott and Grumstrup-Scott, 1992). A woman's body composition and size affect all the components of fitness and physical performance. The average female soldier weights 20% less than the average male soldier, has 10% more body fat, and has 30% less muscle mass (Fitzgerald, Vogel, Daniels, et al., 1986; Vogel, 1992). This larger quantity of body fat is only stored energy and does not contribute directly toward muscular activity. It is "dead weight" that must be transported by the skeletal muscle and can therefore be compared to carrying excess baggage. A minimum amount of fat tissue, called essential fat, is needed to protect body organs and cell structure and to meet limited metabolic needs. This minimum amount has been estimated to be 12% of body weight in women and 3% of body weight in men (McArdle, Katch, and Katch, 1991). A woman stores the bulk of this additional 9% essential fat in the breasts and surrounding the reproductive organs (McArdle, Katch, and Katch, 1991; Wells, 1991). Women have approximately 30% less fat-free mass than men, which limits their ability to produce muscular force (Fitzgerald, Vogel, Daniels, et al., 1986). Greater fat-free mass in men, particularly greater skeletal muscle mass, is primarily related to androgen-stimulated skeletal muscle hypertrophy (Fleck and Kraemer, 1987).

Performance measures such as load carriage, repetitive lifting, and heavy lifting have been shown to be correlated with fat-free mass but have little relationship with body fat. Harman and Frykman (1992) discussed correlations of physical performance and body composition. As shown in Table 1, activities that required a high aerobic capacity (2-mile-run time) were positively correlated with body fat, indicating that soldiers with more body fat had a greater (that is, slower) run time. Activities that required a great deal of strength (such as heavy lifting) were better correlated with fat-free mass in both men and women. As women have more body fat and less fat-free mass, they are more likely to have slower run times and lower strength levels.

Table 1. Correlation of Physical Performance and Body Composition

	% Body Fat		Fat-Free Mass	
	Men	**Women**	**Men**	**Women**
Maximum box lift*	0.06	0.10	0.45	0.26
Maximum machine lift†	-0.15	-0.08	0.61	0.39
Two-mile run†	0.51	0.42	0.01	-0.05

* Teves, Wright, and Vogel, 1985.
† Fitzgerald, Vogel, Daniels, et al., 1986.

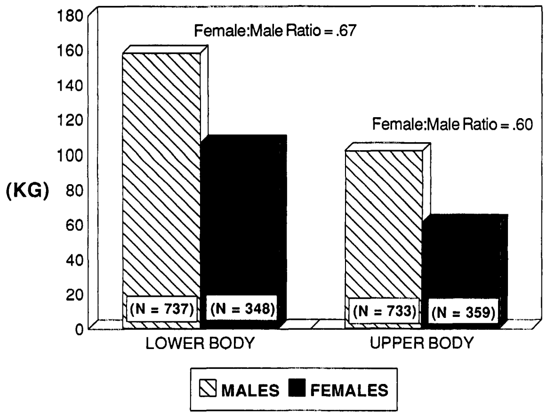

Figure 1. Upper- and Lower-Body Isometric Strength of Men and Women.

Muscular Strength

Strength is defined as "the maximal force a muscle or muscle group can generate at a specified velocity" (Fleck and Kraemer, 1987). One activity in which strength is the primary determinant of performance is lifting a heavy load. Isometric or static strength is the maximal force produced at zero velocity. Maximal torque exerted over a range of motion against a resistance is defined as dynamic strength and includes isokinetic (controlled velocity) and isotonic or isoinertial strength (uncontrolled velocity).

In U.S. Army soldiers, women produced 60–70% of the isometric force of men, as shown in Figure 1 (Knapik, Wright, Kowal, et al., 1980). The female-to-male ratio of isometric strength was greater for measures of lower-body strength (0.67) than measures of upper-body strength (0.60) (Knapik, Wright, Kowal, et al., 1980). This may be partially explained by the quantity of muscle mass in these regions. In a study of healthy young adults it was determined that the female-to-male ratio of muscle mass was 0.65 for the legs and 0.59 for the arms (Fuller, Laskey, and Elia, 1992). This is nearly identical to the ratios for isometric strength (Knapik, Wright, Kowal, et al., 1980). Some additional difference in strength may be explained by differences in habitual activity. It is likely that the leg activity of women (walking, running, climbing stairs) is more similar to that of men than their upper-body activity.

While it is clear that the average man is stronger than the average woman, some women are stronger than some men. This is indicated in Figure 2 *top*, which depicts the overlap of the strength distributions for men and women for a measure of whole-body isometric strength. The strength distribution curves overlapped more when the strength scores were normalized for body mass, as in Figure 2 *center*, and still further when normalized for fat-free body mass, as in Figure 2 *bottom*. When observed strength is corrected for differences in muscle mass, most of the gender difference disappeared. This supports the conclusion that the ability of muscle to produce force is similar between the genders, but the quantity of muscle mass available to produce force differs (Miller, MacDougall, Tarnopolsky, et al., 1993).

Dynamic measurements of strength are often more highly correlated with job performance than measures of isometric strength (Kroemer, 1983; Oseen, Singh, Chahal, et al., 1992). The female-to-male strength ratio for a maximal lift on a weight stack machine was 0.50, as illustrated in Figure 3 (McDaniel, Skandis, and Madole, 1983; Teves, Wright, and Vogel, 1985; Sharp and Vogel, 1992). Note the small amount of overlap in floor-to-shoulder-height lifting strength. Less than 2% of the men scored 36 kg or less, which was equal to the 92nd percentile in women (Sharp and Vogel, 1992). A larger gender difference for weight-stack-machine lifting than for isometric strength suggests other aspects of gender differences in performance, such as technique and expe-

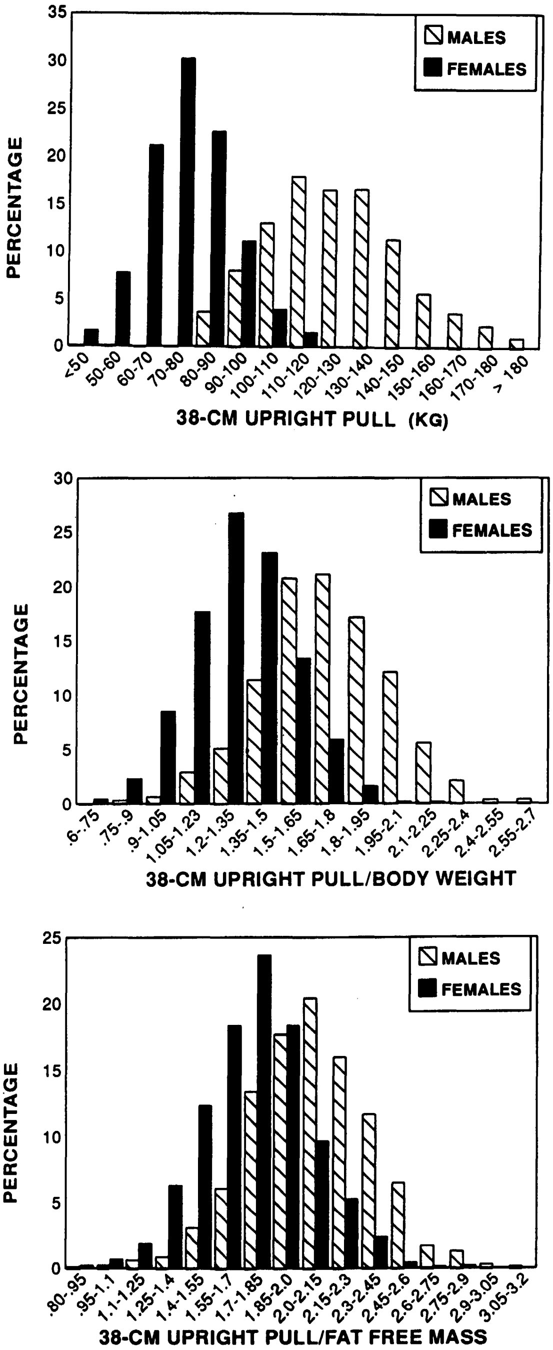

Figure 2. (*Top*) Isometric Lifting Strength Distributions of Men and Women. (*Center*) Isometric Lifting Strength Distributions of Men and Women Relative to Body Weight. (*Bottom*) Isometric Lifting Strength Distributions of Men and Women Relative to Fat-Free Weight.

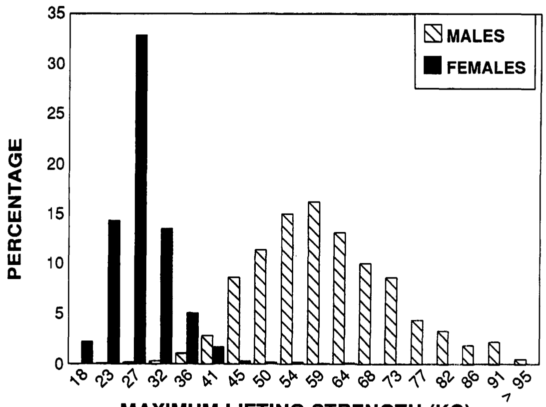

Figure 3. Maximum Lifting Capacity Distribution of Men and Women.

rience. When asked to lift a maximally loaded box from the floor to shoulder height, women were able to lift 60% as much as men (Myers, Gebhardt, Crump, et al., 1984; Kroemer, 1983; Teves, Wright, and Vogel, 1985; Beckett and Hodgdon, 1987). This may indicate that women are more comparable to men when performing "real-world" lifting tasks (box lift) than when performing an artificially controlled task (lifting a weight-stack device). The box lift is more familiar and allows more room for variation in lifting technique. Women may be better able to accommodate for strength differences when performing familiar tasks where the technique can be varied.

Muscular Endurance

Muscular endurance can be defined as the ability to maintain an isometric force or a power output involving dynamic contractions (McArdle, Katch, and Katch, 1991). When exercising at a given percentage of maximal strength, females demonstrated muscular endurance equal to or greater than their male counterparts (Miller, MacDougall, Tarnopolsky, et al., 1993; Maughan, Harmon, Leiper, et al., 1986). The female-to-male ratio for soldiers performing a hand-grip endurance test at 60% of hand-grip strength ranged from 1.03 to 1.19 over four testing sessions, and no significant gender differences were found (Teves, Vogel, Carlson, et al., 1986). When lifting repetitively with an absolute external load (that is, number of bench-press repetitions with a 45-pound bar), males demonstrated greater muscular endurance since their absolute strength was greater (Myers, Gebhardt, Crump, et al., 1984; Beckett and Hodgdon, 1987; Sharp, Wright, Vogel, et al., 1980). When lifting an absolute load, the average woman used a greater percentage of her maximum strength than the average man. Because she works at a greater percentage of her capacity, a woman will become fatigued faster than a man when handling a heavy absolute load.

To perform adequately in tasks designed for and typically performed by men, a woman must maintain a "strength reserve." She needs to be strong enough so that the tasks she is required to perform represent the smallest factor of her maximum strength as possible. For example, if she is required to load 40-pound boxes and her maximum lifting strength is 40 pounds, she will fatigue rapidly. If her maximum lifting strength is 100 pounds, she will be able to lift 40 pounds repeatedly.

Another example of a task that requires muscular endurance is sprinting a short distance with a loaded pack or rapidly evacuating patients. These activities are high-intensity tasks, generally lasting no longer than 60 seconds, where an all-out effort is made. There are several tests that are used to estimate this capacity for short, intense exercise: dashing 50–200 yards, all-out cycling, and sprinting up stairs (McArdle, Katch, and Katch, 1991). One performance test used by the army is the Wingate test (Murphy, Patton, and Frederick, 1986), a 30-second, maximal leg-cycling or arm-cranking test in which the pedal resistance is adjusted for body weight. Peak power is the highest power output achieved in any 5-second period and typically occurs during the first 5 seconds. Peak power is thought to indicate the capacity to utilize immediate energy sources or the adenosine-triphosphate, creatine phosphate (ATP-CP) system. The ATP-CP system is primarily responsible for energy during the first 10 seconds of exercise. Mean power is the average power output during the entire 30 seconds on the Wingate test. It is used to indicate the capacity of the short-term energy system or the glycolytic system. This glycolytic system is the primary

Table 2. Female-to-Male Ratio for Peak and Mean Power of Army Men and Women Performing a Wingate Test*

	Female-to-Male Ratio	
	Peak Power	**Mean Power**
Power	0.65	0.60
Power/body weight	0.82	0.78
Power/fat-free mass	0.90	0.83

* Murphy, Patton, and Frederick, 1986.

source during exercise lasting from 10 seconds to 2 minutes (McArdle, Katch, and Katch, 1991). The resulting female-to-male ratios for peak and mean power of army men and women performing this test are shown in Table 2. The female-to-male ratio was higher for peak power than for mean power. As with measures of strength, the female-to-male ratios for peak and mean power improved when the value was expressed relative to body weight and fat-free mass.

Cardiopulmonary Fitness

The capacity to carry out prolonged activity is determined by maximal aerobic power. Aerobic power is defined as the highest rate at which the body can utilize oxygen and is measured as maximal oxygen uptake ($\dot{V}O_2max$). Aerobic power is a main determinant of one's ability to sustain submaximal exercise lasting longer than 5 minutes. $\dot{V}O_2max$ can be measured while performing many different types of exercise, such as running, cycling, lifting, or swimming. Absolute oxygen uptake is expressed in liters per minute ($l \cdot min^{-1}$) and, relative to body mass, is expressed as milliliters per kg of body weight per minute ($ml \cdot kg^{-1} \cdot min^{-1}$). Women have a lower $\dot{V}O_2max$ than equally trained men, regardless of the manner in which that capacity is expressed, as shown in Table 3. The female-to-male ratio of soldiers at the end of Army Basic Training was 0.63 when expressed in absolute terms and 0.75 when expressed relative to body weight (Patton, Daniels, and Vogel, 1980). Even female West Point cadets, who rank as the army's most elite, were not much closer to their male counterparts in terms of aero-

Table 3. Aerobic Capacity of Men and Women in Basic Training* and at West Point Military Academy†

	Basic Trainee		Cadet	
	Male	**Female**	**Male**	**Female**
$l \cdot min^{-1}$				
Mean	3.76	2.67	4.27	2.86
SD	(0.43)	(0.42)	(0.40)	(0.29)
$ml \cdot kg^{-1} \cdot min^{-1}$				
Mean	53.6	39.2	60.6	49.7
SD	(4.4)	(3.8)	(4.7)	(4.2)

* Patton, Daniels, and Vogel, 1980.
† Daniels, Kowal, Vogel, et al., 1979.

bic power. The female-to-male ratio for West Point cadets was 0.67 expressed in $l \cdot min^{-1}$ and 0.82 expressed in $ml \cdot kg^{-1} \cdot min^{-1}$ (Daniels, Kowal, Vogel, et al., 1979). This translates into a lower capacity to perform aerobic exercise at an externally derived exercise rate. Thus, during a constant-paced road march, women would exercise at a higher percentage of their aerobic power than men and fatigue faster.

There are several basic physiological differences between men and women that cause these differences in aerobic capacity. The greater quantity of fat-free mass, or exercising muscle mass, in men results in a greater absolute $\dot{V}O_2max$ ($l \cdot min^{-1}$). Relative $\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$), however, is greatly influenced by excess body fat. By increasing the denominator (kg body weight) the resulting $\dot{V}O_2$ is reduced. The quantity of body fat increases the amount of metabolically inactive tissue that has to be moved by the active muscle mass.

Differences in hemoglobin levels also influence the gender differences in aerobic capacity. Women have 6% fewer red blood cells and 10–14% less hemoglobin than men (Wells, 1991). The increased hemoglobin concentration in men enables them to circulate more oxygen per unit of blood. There are also differences in a woman's capacity to pump blood through the system. A woman's maximum cardiac output, or the quantity of blood pumped by the heart per minute, is 30% less than a man's cardiac output (Wells, 1991). Cardiac output is determined by two factors: stroke volume and heart rate. Stroke volume is the quantity of blood pushed out of the heart with each beat. Women have a smaller heart and heart volume, which results in a smaller stroke volume, than men. Because stroke volume limits cardiac output, a woman's heart rate will be higher than a man's heart rate at any given cardiac output. In order to maintain an equivalent supply of oxygen to working muscles, a woman must increase her cardiac output to make up for a decreased oxygen carrying capacity, that is, a lower hemoglobin content (Wells, 1991).

PHYSICAL TRAINING

Thus far the gender differences described have assumed that men and women are at an equal level of physical training. Determining level of training is difficult and time consuming. Appropriate physical training not only improves the performance of athletes but can also improve job performance (Genaidy, Karwowski, Guo, et al., 1992). To be effective, physical training must be specifically designed to stress the appropriate muscle groups and energy systems needed to perform an activity. For example, long-distance running will not improve upper-body weight-lifting performance. The responses of military men and women to basic training have been examined, and some research has been done to examine the effects of physical training on the occupational performance of army women. Physiologically, women are at a disadvantage when physically competing against men (less muscle mass, more body fat, lower red blood cell count, lower hemoglobin levels, smaller cardiac outputs, and so on). While physical training can be used to increase the physical capacity of women, gender differences cannot be completely eliminated with training.

Strength Training

Progressive resistance training, or weight training, is a highly effective method of increasing muscle strength. Based on the intensity of the training program, it can also be used to improve muscular endurance. The heaviest weight that can be handled for 6 repetitions of a movement generally produces optimum strength gains, while a weight that can be moved for 15 or more repetitions will produce improvements in muscular endurance (Fleck and Kraemer, 1987; Atha, 1981). Following a progressive resistance training program, women show an equivalent percentage increase in muscular strength as compared to men who begin at a similar state of training. When men and women train with equal intensity, the difference in capabilities does not narrow unless the initial training status differs (Fleck and Kraemer, 1987). The lower one's initial state of training, the more potential there is for improvement. In general, both men and women experience an increase in fat-free mass, a decrease in body fat, and no resultant change in body mass with a weight-training program (Fleck and Kraemer, 1987; Cureton, Collins, Hill, et al., 1988). Increases in fat-free mass with strength training are the results of increases in muscle fiber cross-sectional area (Cureton, Collins, Hill, et al., 1988). Historically, women have avoided weight training for fear of becoming "muscle bound," however, this result is rarely a problem. While men and women have the same percentage increase in muscle fiber size with equivalent training, the resultant muscle mass will be less in women. Men start with larger fibers; therefore, with an equal *percentage* increase in size, the *actual* increase in size is greater in men.

Soldiers who enter the military participate in 8 weeks of basic training followed by specific occupational training of varying length. Basic training includes calisthenics, running, road marches, and common soldiering tasks. Several studies have found significant increases in muscle strength following basic training in both men and women (Knapik, Wright, Kowal, et al., 1980; Teves, Wright, and Vogel, 1985) but have not shown any changes in the female-to-male strength ratio. This indicates that men and women respond similarly to basic training, but basic training does not reduce the strength disparity between them. In a longitudinal study of West Point cadets, the female-to-male ratio did not change for most measures of isometric strength (Daniels, Wright, Sharp, et al., 1982). Knapik, Wright, Kowal, et al. (1980) found isometric strength increases of 4–16% in men and women following basic training; however, strength increases on the order of 40–60% would be needed to have parity between men and women. Increases of this magnitude are extraordinary and are not likely to occur during Army Basic Training (Fleck and Kraemer, 1987; Teves, Wright, and Vogel, 1985; Jette, Sidney, Regimbal, et al., 1987).

Aerobic Training

While most studies have found no evidence to suggest that the physiologic response to aerobic exercise and training is different in men and women (Daniels, Kowal, Vogel, et al., 1979; Daniels, Wright, Sharp, et al., 1982; Drinkwater, 1984), others have found gender differences in the production of oxidative enzymes (Wells, 1991). The majority of the gender difference in percentage increase in $\dot{V}O_2max$ following a training program are generally attributed to differences in initial training status. The increase in aerobic capacity from pre- to post-basic training is 5–10%, but this percentage varies with the level of training upon entry (Vogel, 1985). Daniels, Kowal, Vogel, et al. (1979) reported that the difference in aerobic power between male and female cadets was 22% on entering West Point Military Academy and was reduced to 18% following 6 weeks of endurance training. These authors conclude that the men had a higher initial state of training and did not benefit from the training program as much as the women cadets, whose $\dot{V}O_2max$ increased 7.9%. This finding is similar to the findings of Patton, Daniels, and Vogel (1980), who reported that soldiers entering basic training at a high level of aerobic fitness showed little or no improvement, while less-fit soldiers increased with basic training. In a second study of male and female West Point cadets, Daniels, Wright, Sharp, et al. (1982) found that 2 years of military training did not improve the female-to-male ratio for $\dot{V}O_2max$.

Occupational Training

While strength and aerobic training may not result in women attaining physical capacities equal to men, it may enable them to adequately perform many physically demanding jobs. An example of a physically demanding combat-arms task is the loading and firing of a 155 mm towed howitzer. The 45 kg projectiles must be lifted to chest height and placed in a loading mechanism. A study was conducted to determine if women are physically capable of meeting army performance standards on this equipment (Murphy and Nemmers, 1978). The women were trained for 3 weeks with jogging and weight training and were also trained to load and fire the howitzer. At the end of the 3 weeks, all women were capable of loading and firing the projectiles at the required rate, and some women actually exceeded the requirements.

RESEARCH EXAMINING THE PERFORMANCE OF MILITARY TASKS BY WOMEN

On average, women have less physical capacity for exercise than men, with much of the gender differences the result of uncorrectable differences in muscle mass. This does not mean that women soldiers are incapable of adequately performing many physically demanding military tasks. If the intensity of the task does not require a maximal effort, or if she is allowed to self-pace, a woman can perform many tasks and meet the male standard of performance. Tasks that do require a near-maximal effort by women might be redesigned to reduce the physical demands, modified by mechanical performance aids, or performed in teams. If the task cannot be redesigned, an alternative is to recruit personnel for the job who are already capable of performing the task.

One means to reduce the physical demand on women is to allow them to self-pace whenever possible. When allowed to self-pace while backpacking with equal loads, both genders self-paced at the same relative exercise intensity of 45% $\dot{V}O_2max$ (Evans, Winsmann, Pandolf, et al., 1980). However, because they walked at a speed that produced an equivalent relative exercise intensity (% $\dot{V}O_2$-max), female soldiers traveled at a slower speed.

Military tasks, for the most part, have been designed around the ability of the average man. Most tasks are not self-paced or of a submaximal nature, therefore, women must exercise at a greater percentage of their physical capacity to meet the expected male standard. In a study by Martin and Nelson (1985), male and female ROTC students were asked to perform speed and agility tests (for example, sprinting, climbing, and jumping) while carrying a backpack. As the backpack load was increased, performance on these tests decreased at a faster rate in women than in men. When the amount of load carried is expressed relative to fat-free mass, the increase in heart rate with an increase in load was the same for men and women (Monod and Zerbib, 1985). However, an absolute load represents a greater relative exercise intensity for women than for men, resulting in more rapid fatigue.

In addition to redesigning stressful tasks, it is critical that equipment be tested on women. A study is currently being conducted to determine the effects of chemical protective clothing on the energy cost and heart rate response to low-, moderate-, and high-intensity army tasks in men and women (Patton, unpublished protocol, 1991). One of the moderate-intensity tasks being employed in the study is carrying a 22 kg backpack on a treadmill at 3.3 mph. It was found that women exercised at a higher percentage of $\dot{V}O_2max$ than men in both standard military uniform and in chemical protective clothing (Murphy, Patton, Mello, et al., 1993). Wearing chemical protective clothing increased the energy cost and heart rate for both genders, but the percentage increase was greater for women than for men (Murphy, Patton, Mello, et al. unpublished observation, 1993). Exercising at an externally determined pace is more physically stressful on women than men, and exercising while wearing chemical protective clothing compounds the problem further.

Heat injuries are a problem when working in chemical protective clothing because the heat cannot be dissipated by evaporative sweating. Women are at greater risk of heat injury in chemical protective clothing 1) because they are working at a higher percentage of their maximum capability and 2) because they tend to have more difficulty dissipating heat (Kolka, 1992).

The U.S. Army field medical specialist is an occupation commonly filled by women and one that involves the physically demanding task of transporting an injured person by stretcher. Concerns have been raised regarding the ability of women to adequately perform this task (Reed, 1990). One means of changing the task is to provide an aid to carrying performance. A study was conducted to determine the effectiveness of a shoulder harness in reducing the load on the hand and arm during two different stretcher carrying tasks and to compare the performance of men and women on these tasks (Rice, V. J., unpublished observation, 1991). A maximal-effort stretcher-carrying task, designed to simulate the rapid loading of a medical evacuation helicopter, required soldiers to carry a stretcher loaded with an 81 kg dummy 50 meters and lift that weight to the height of the helicopter bed. This task was completed with and without a shoulder harness in two- and four-person carrying teams. When asked to complete as many cycles as possible in 15 minutes, men completed 18 rescues and women completed nearly 15, resulting in a female-to-male ratio of 0.82. The shoulder harness did not result in a change in the number of carries completed or a decrease in heart rate during the task, but the perception of effort was significantly lower when the harness was used during the two-person maximal-effort carrying task (Rice, V. J., unpublished observation, 1991).

In a field test of an improved harness, teams of two women did not complete more carries with a harness but did complete the carry with no rest stops. Without a harness the women had to put the stretcher down and rest four times per 50-meter carry (Rice, 1992). Simply raising and lowering the 81-kg patient load four times is a physically demanding task and puts the patient at increased risk of being dropped or jarred. When interviewed, women reported they would use a harness for stretcher-carrying, while men felt harness use would be situationally dependent (Rice, 1992).

In a second task where soldiers carried the stretcher at a slow speed until exhaustion, the female-to-male ratio for carry time was 0.43 without the harness. Use of the harness resulted in a marked improvement for men and women and increased the female-to-male performance ratio to 0.65 (Rice, V. J., unpublished observation, 1991). The harness represents an inexpensive, effective way to improve the performance of women during a prolonged stretcher carry. This illustrates how some physical tasks can be modified to better accommodate the physical limitations of women.

Another example of task redesign or accommodation is the use of teamwork to accomplish individual tasks. Military Standard 1472 D (Military Standard Human Engineering Design Criteria for Military Systems, Equipment and Facilities, 1989) sets standards for safe loads. For loads greater than 20 kg, it is recommended that soldiers work in teams. Indeed, many army jobs require the use of teams to perform heavy-lifting tasks. Working in teams is also a means for low-strength women to perform heavy-lifting tasks they would otherwise be unable to perform. A study was conducted to compare the team lifting strength of men and women soldiers in teams of two, three, and four persons. Subjects performed a maximal lift from floor to knuckle height. As expected, the teams with the greatest number of men lifted the heaviest loads. To consider the potential of the individual lifter, the percentage of the sum of individual lifting strengths represented by the team lifting strength was calculated: (% sum = team lifting strength/each team member's individual lifting strength). In two- and three-person teams, the % sum was significantly greater in single-gender teams than in mixed-gender teams. In four-person teams there was no significant difference between the % sum for groups of four women, four men, or two women with two men. The lifting strength of two women was 114% that of one man; therefore, two women could be expected to accomplish a heavy-lifting task designed for one man (Sharp, Rice, Nindl, et al., 1993). The female-to-male ratios for maximum lifting strength and the % sums in teams of two, three, and four are shown in Table 4. Team lifting is a sensible and viable solution in a peacetime environment to enable women to perform the heavy-lifting tasks required of many military jobs. During combat, however, the loss of one person may render the lifting partner ineffective until another partner is available.

Rather than redesigning the tasks, another solution is to recruit soldiers who already meet the physical requirements of the job. One report concluded that "if they [the military] want strong women, they will need to recruit strong women, women who at the time of their recruitment can already meet the contemplated standards" (Jette, Sidney, Regimbal, et al., 1987). This was the focus of a study conducted on a large group of male and female basic trainees (Teves, Wright, and Vogel, 1985). Based on task analyses, the cardiovascular and strength demands of all army occupational specialties were determined. The specialties were grouped into five categories according to physical demands (Vogel, Wright, Patton, et al., 1980). A series of preemployment tests was designed and tested on approximately 1,000 men and 1,000 women entering basic training (Teves, Wright, and Vogel, 1985). These same soldiers were asked to perform a series of job-related tasks (lifting, carrying, pushing, and pulling) at the end of basic training (Myers, Gebhardt, Crump, et al., 1984). The screening tests were used to predict performance on the job-related tasks, and a single measure of lifting capacity was determined to be the best predictor of job performance (Myers, Gebhardt, Crump, et al., 1984). The test was given to all soldiers entering the army for several years, but meeting the lifting standard was not a mandatory requirement for entrance into an occupational specialty. The effectiveness of the test was never determined, and it was eventually dropped as a cost-cutting measure. This line of research shows much promise, however, and further research is planned.

CONCLUSIONS

Military service is physically demanding, even in jobs rated as having low physical demands, due in part to the need to perform common soldiering tasks. Historically, military tasks have been designed for the physical capabilities of the average man. The average woman does not have the same physical capacity, nor can she be trained to have the same physical capacity as the average man. An overly simplistic solution would be to return to an all-male force. Fortunately, this is not the direction in which the U.S. armed forces are moving. More direct-combat occupations are being opened to women, and most are very physically demanding (Council and Ostendorf, 1993). From a supply-and-demand perspective, there are not always enough male volunteers with the requisite skills to fill the military's needs in an all-volunteer force. Therefore, it is important to continue integrating women with high intellectual abilities and technical skills into the armed services.

In a time of budget cutting and reductions in

Table 4. Individual Lifting Strength and Percentage Sum for Teams of Two, Three, and Four Men and Women and the Female-to-Male Ratio*

	Men (kg)	Women (kg)	Female-to-Male Ratio
Lifting strength (kg)	137.0 ± 22.1	84.7 ± 14.2	0.62
Two-person team	0.90	0.92	0.62
Three-person team	0.85	0.91	0.62
Four-person team	0.86	0.90	0.64

* Sharp, Rice, Nindl, et al., 1993.

force, it is more critical than ever that all soldiers be fully capable of performing their occupational specialties. Therefore, all soldiers, men and women, must perform their occupational specialties up to the standards established for successful job performance. Physical training may allow some women and low-strength men to perform at the standards required of physically demanding jobs, but other solutions should also be considered. Some tasks can be redesigned or modified to reduce physical stresses. Mechanical aids or job assists can be used, such as the shoulder harness for litter carriage. Whenever possible, women and low-strength men should be allowed to self-pace or work in teams to accomplish tasks. If a task cannot be redesigned and the average woman or low-strength man cannot be physically trained to perform the task adequately, then incoming soldiers (men and women) must be matched to the physical demands and job requirements of occupational specialties. The best candidates for each job can then be selected from the pool of available applicants.

Research is currently being conducted on the issues of women's physical capacity and job performance, and more information is needed to properly accomplish the goal of fully integrating women into the U.S. Army. Members of the U.S. Army Research Institute of Environmental Medicine are currently conducting a study of women basic trainees, examining the relationships of initial physical fitness and body composition levels and physical performance following 8 weeks of basic training. Such studies will enhance the army's ability to properly place and employ women in the military service, thereby increasing their contributions to national defense.

There has been much attention focused recently on the lack of research on women's health issues. This review illustrates that the military has been in the forefront of addressing women's physical performance and has pursued an active research program to bring about an efficient match between women's capabilities and the army's needs.

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