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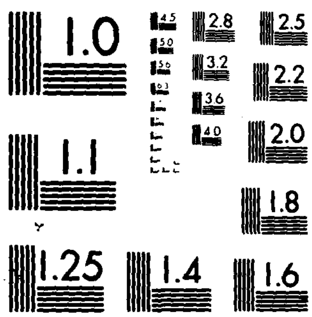

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Eighteen cadets (11 males, 7 females) were studied on five occasions during their first two years of training at the U.S. Military Academy. Studies began during their first week at the Academy and continued until the end of the second academic year. During the study, the regimented lifestyle imposed comparable environmental and dietary factors. VO_2 (l/min), lean body mass and body weight increased significantly in both groups. Per cent body fat was significantly reduced only after the first summer of training and then returned to initial values. VO_2max (ml/kg.min) did not change in males during the study. However, females increased significantly

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after the initial 6 weeks of training (44.2 to 48.8 ml/kg.min). They remained at this level through the second summer of training. However, by the end of their second academic year, females' values dropped to 45.9 ml/kg.min. Maximal isometric strength measured 30-40% higher in males than in females. During the last year of training, arm and shoulder strength increased (9.3%) in males but was unchanged in females. Our results suggest that even extended military training did not enable females to significantly narrow the difference with male cadets in terms of muscle strength and aerobic power.

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The Effect of Two Years Training on Aerobic Power and Muscle Strength of Male and Female Cadets.

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Running Head: Training of Male and Female Cadets.

Eighteen cadets (11 males, 7 females) were studied on five occasions during their first two years of training at the U.S. Military Academy. Studies began during their first week at the Academy and continued until the end of the second academic year. During the study, the regimented lifestyle imposed comparable environmental and dietary factors. $\dot{V}O_2$ (l/min), lean body mass and body weight increased significantly in both groups. Per cent body fat was significantly reduced only after the first summer of training and then returned to initial values. $\dot{V}O_2$ max (ml/kg•min) did not change in males during the study. However, females increased significantly after the initial 6 weeks of training (44.2 to 48.8 ml/kg•min). They remained at this level through the second summer of training. However, by the end of their second academic year, females' values dropped to 45.9 ml/kg•min. Maximal isometric strength measured 30-40% higher in males than in females. During the last year of training, arm and shoulder strength increased (9.3%) in males but was unchanged in females. Our results suggest that even extended military training did not enable females to significantly narrow the difference with male cadets in terms of muscle strength and aerobic power.

Long-term exercise, sex differences, cardiorespiratory fitness, lean body mass, treadmill.

Recently, there has been considerable interest in the military concerning the physical fitness levels of females, their responses to physical training, and comparisons of males and females in terms of physical fitness. Much of this interest has been generated by the large increase in the number of women in the services and their entrance into job specialities which have been traditionally held by males. While there have been many reports of the effects of training on females (4,7) and even reports comparing males and females in the same training program (2,3), these studies involved training of relatively short duration (6-8 weeks). It is not known how extended military training will affect the differences in the levels of fitness which have been reported between genders. The purpose of this study was to compare the responses of male and female cadets to extended military training at the U.S. Military Academy. During the course of the study, the training program of both male and female cadets was similar and in some respects identical. At all times the regimented life style imposed comparable environmental and dietary factors.

METHODS

Eighteen cadets (11 males, 7 females) completed all phases of this study. These volunteers were part of a group of 60 cadets who were studied before and after the initial summer training program which all cadets undergo and has been described elsewhere (3). For this study subjects were evaluated on five separate dates listed in Table 1. These dates were selected so that they coincided with the beginning and the end of the training programs which all cadets undergo during their first two summers. The final test date was at the end of their second academic year.

The training during the first summer was six weeks long and similar to an enlisted, initial entry, basic training program. Physical training consisted of calisthentics, grass drills and a 30-minute run 5-6 times per week. For the running, cadets were divided into three groups based upon their performance in a 1.5 mile run. Therefore, duration and frequency were identical while intensity was adjusted to meet an individual's capability. The second summer's training program was designed to give cadets seven weeks of military field training. It included infantry patrolling, hand to hand combat, wilderness survival, as well as daily calisthenics and running. During the academic year, all cadets were required to participate in either an intramural, club or varsity sport and to attend physical education classes. The first year of physical education consisted of boxing and wrestling for males while females were given a course in self-defense. Although the training was not identical during the entire study, it was similar. All cadets led a very active life style and were required to participate in demanding physical activities regularly. The regimented life style which was in effect constantly assured similar dietary, sleeping and recreational habits throughout the study.

Subjects underwent height, weight and skinfold measurements. Skinfolds (bicep, tricep, subscapular and suprailiac) were used to estimate body fat using the formula of Durnin and Wormesley (5). All skinfold and weight measures were performed by the same individual in order to maximize the reliability of the comparisons.

On the last three test dates, subject's muscular strength was assessed with maximal voluntary isometric contractions. Three muscle groups were tested: upper torso (arm and shoulder) flexors, leg extensors and trunk extensors with equipment and procedures previously described (8). Strength of the upper torso was assessed with the subject securely fastened with a lap belt in a sitting position. The upper arms were parallel to the floor with the arms forming a 90°

angle when an overhead bar was grasped. This bar was secured with a stationary cable and the force exerted was measured with a strain gauge transducer.

Strength of the leg extensors was determined by testing the quadriceps femoris muscle. The subject sat securely fastened in a chair with knees bent at 90° and grasped handles on the seat edge for additional stability. The subject exerted outward force on a bar placed against the arch of the feet and connected to a transducer.

Strength of the trunk extensors was assessed with the subject in a standing position with the shoulders strapped to the bar which was connected to the transducer. The subject flexed back against the shoulder harness while driving the pelvic girdle forward against a stabilizing plate.

Another isometric measure involving the arms, shoulders and upper back muscles was also made. For this test, the subject was in a standing position and pulled upward on a bar fixed at a height of 132 cm, which was attached by cable to a force transducer. The transducer was mounted on a plate on which the subject stood. For all the strength measures, two maximal contractions were performed and averaged.

During each session, subjects peformed a running maximal oxygen uptake ($\dot{V}O_2$ max) determination. The test used was a modification of the test used by Mitchell et al (10). The test began with a warm-up run for 6 minutes, followed by a 5-10 minute rest period. Two to four additional runs were performed, each 3-4 minutes long and interrupted by rest periods. Workloads were increased by raising speed and/or grade. During the last minute of each run, expired air was collected in plastic Douglas bags through a mouthpiece and Kogel y-valve. A plateau in O_2 comsumption with increasing workload was considered indicative of $\dot{V}O_2$ max. A plateau was defined as an increase of less than 2.0 ml/kg•min with an increase of 2.5% grade. Expired air was analyzed with a Beckman LB-2 CO_2 analyzer and a Model S3-A oxygen analyzer from Applied Electrochemistry, Incorporated. Volumes were measured with a Tissot spirometer. Ratings of perceived exertion were recorded during the last minute of each run using a Borg scale (1). Heart rate was monitored using a modified V_5 electrocardiograph recording.

Statistical comparisons were made using an analysis of variance for repeated measures. Tukey's HSD test was used for post-hoc comparisons. For statistical significance, we used $p \leq 0.05$.

RESULTS

Table 2 lists the physiological data collected on males during the testing period. $\dot{V}O_2$ max (ml/kg•min) and HR max did not change significantly during the entire study. In contrast, $\dot{V}O_2$ max (liter/min) did increase significantly along with body weight over the two year period. This weight increase in males was due exclusively to an increase in lean body mass (LBM) since body fat was reduced only after the first summer's training. Minute ventilation (BTPS) increased at the end of each summer's training and remained elevated throughout the second academic year.

Table 3 lists the physiological data that was collected from female cadets during this study. In contrast to the male cadets, females underwent a significant increase in $\dot{V}O_2$ max (ml/kg•min), however there was a decrease over the course of the second academic year. A similar trend is seen in the female cadets in $\dot{V}O_2$ max (l/min) and LBM. Like the males, females showed a decrease in % body fat after the first summer's training. However, by the beginning of the second summer both groups had % body fat values similar to that at which they started. HR max and minute ventilation (BTPS) changed significantly in the females and was associated with the summer training programs.

The results of the maximal isometric strength testing are listed in Table 4. This testing was performed before and after the second summer's training and after the second academic year. No data was available for the leg extensors at the end of the second academic year due to technical problems with that measure. Over the summer of 1978, both males and females showed increased leg extensor strength (6.9 and 8.3% respectively). This increase was statistically significant for males ($p < 0.01$) but not for females. Males showed larger increases in both measures of upper body strength than females between June, 1978 and May, 1979. On the upright pull, males increased by 6.7% (NS) and females by 4.6% (NS). Upper torso strength for males increased by 9.7% ($p < 0.01$) while females had a 3.7% increase (NS) in strength. On all strength measures the values for female cadets averaged approximately 30-40% lower than their male counterparts.

Trunk extensor maximal isometric strength declined over the summer of 1978 but returned to their initial levels when measured in May, 1979. While unsure of the actual cause for this phenomenon, it seems much likelier to be due to fatigue resulting from some aspect of the summer training program rather than an actual decrease in muscle strength.

DISCUSSION

The results of this study indicated that even after two years training, female cadets did not narrow the gap between them and their male counterparts in terms of aerobic power and muscle strength. Both males and females started this study in a fairly high state of fitness. Initial aerobic power measurements in both male and female cadets are comparable to values reported for college aged athletes (4,6). The high level of fitness is probably responsible for the lack of an increase in aerobic power (ml/kg•min) in males. However, the effect of the training on the males is apparent when one examines changes in $\dot{V}O_2$ max (liter/min), lean body mass (LBM) and upper torso strength. It is interesting to note that males were able to retain their high $\dot{V}O_2$ max while they increased body weight. Females, on the other hand, had significant increases in aerobic power and lean body mass but not in any of the muscle strength measures. Females showed a characteristic response to an aerobic training program during the first summer. They maintained this level of fitness through the second summer but had a drop in aerobic power when tested at the end of their second academic year. This decrease in aerobic power was associated with a decrease in minute ventilation, body weight and lean body mass. It appears as though the females underwent a period of detraining over the course of the second academic year. However, it must be pointed out that both males and females were in excellent physical condition when compared to a similar aged group (6,11).

In an effort to determine the cause for the decrease in aerobic power we evaluated questionnaires given to each cadet, regarding injury and illness. During the course of the second academic year, 5 of the 7 female cadets were restricted for some period of time (4 days to 6 weeks) from performing physical training for medical reasons. On the other hand, only 2 of the 11 males had such restrictions, both for three weeks (Table 5). This difference betwen males and females in loss time in training is characteristic of the pattern that is seen in all cadets (personal communication, Louis Tomasi, A.T.C., USMA, West Point, NY). It therefore appears that women are more susceptible to injury/illness as a result of this type of lifestyle and that this may contribute to the detraining affect seen in this study. Even though the length of restriction was fairly short in all the cases listed above, the fact that the injury rate was so much higher in females than in males may mean that, because of untreated, minor injuries or discomforts, they were unable to train at the frequency, duration and intensity required to maintain an exceptionally high level of fitness. However, further studies are required in order to substantiate this hypothesis.

Unlike males, females did not show any significant changes in upper torso strength. Studies in animals indicate that males have greater capacity for improving muscle strength and mass than females (9). The results of the present study agree with those findings and indicate that the training stimulus did not cause significant changes in muscle strength of female cadets. However, it should be noted that most of the strength gains occurred during the summer program when training was virtually identical. Therefore, females may not be physiologically able to respond to the training in the same manner as males as regards muscle strength.

Both male and female cadets had greater aerobic power and muscle strength when compared with enlisted military counterparts. A group of males and females were recently tested at the end of the 6-week basic training program (11). Males had a $\dot{V}O_2$ max (ml/kg•min) of 52.3 ± 3.8 and females were at 39.3 ± 3.5. The male and female cadets had values for aerobic power that were approximately 15% and 20% higher, respectively. Male and female cadets had lower % body fat levels, also. At the end of basic training the males averaged 14.5 ± 3.8% body fat and females averaged 26.2 ± 3.8% body fat.

In terms of muscle strength, male and female cadets were stronger than basic trainees in upper torso and leg extensor measures. There was no difference in trunk extensor measurements (unpublished data from this laboratory).

The results of this study demonstrate that male and female cadets have greater aerobic power, less body fat and are stronger than a similar aged military enlisted group who performed the same tests. The female cadets did not significantly narrow the discrepancies with male cadets in terms of muscle strength and aerobic power, even after two years of similar training. These results support the theory that most of the difference observed between males and females in aerobic power and muscle strength is due to genetically determined physiological differences rather than social, cultural and environmental differences in state of training.

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Table 1. Schedule for Testing.

1. June 1977 — Aerobic Power
   1st Summer of Training

2. August 1977 — Aerobic Power
   1st Acdemic Year

3. June 1978 — Aerobic Power & Muscle Strength
   2nd Summer of Training

4. August 1978 — Aerobic Power & Muscle Strength
   2nd Academic Year

5. May 1979 — Aerobic Power & Muscle Strength

Table 2. Physiological Data Collected During Maximal Exercise Testing Of Males.

N=11	June 1977	August 1977	June 1978	August 1978	May 1979	Tukey's HSD
$\dot{V}O_2$ max (ml/kg.min)	58.5 3.5	60.1 3.9	60.8 4.2	59.9 3.4	60.3 2.8	NS
$\dot{V}O_2$ max (L/min)	4.13 .46	4.21 .31	4.41 .34	4.43 .45	4.54 .41	.21
HR_{max} (bts/min)	190 6	185 6	190 7	189 6	188 7	NS
$\dot{V}_E$ BTPS (L/min)	140.1 19.3	150.5 29.3	141.4 19.3	157.6 16.9	156.6 22.2	13.3
Wt (kg)	70.5 8.1	69.9 7.7	72.2 8.0	74.1 8.0	75.0 8.4	1.6
% Body Fat	12.1 2.3	9.7 3.0	12.1 2.3	12.1 2.3	12.1 2.8	1.3
LBM (kg)	62.4 6.5	63.5 6.4	63.9 6.3	65.3 6.5	66.0 6.6	1.1

Values expressed as $\bar{x}$ ± S.D.

Table 3. Physiological Data Collected During Maximal Exercise Testing Of Females.

N = 7	June 1977	August 1977	June 1978	August 1978	May 1979	Tukey's HSD
$\dot{V}O_2max$ (ml/kg.min)	44.2 4.8	48.8 3.7	48.1 4.4	49.0 4.4	45.9 2.8	3.11
$\dot{V}O_2max$ (L/min)	2.47 .26	2.74 .24	2.78 .29	2.91 .28	2.67 .14	.26
HR_{max} (bts/min)	193 7	186 9	193 6	186 7	192 5	7
$\dot{V}_E$ BTPS (L/min)	90.8 17.4	105.1 14.5	93.6 17.6	107.4 19.1	100.7 10.8	16.6
Wt (kg)	56.1 3.9	56.2 3.0	57.9 4.0	59.4 3.2	58.3 3.2	2.0
% Body Fat	22.4 3.3	19.3 2.4	21.3 2.6	21.9 2.8	21.0 3.1	1.8
LBM (kg)	43.5 1.9	45.2 1.6	45.5 2.1	46.3 1.4	45.9 1.7	1.3

Values expressed as $\bar{x}$ ± S.D.

Table 4. Maximal Isometric Strength.

	June 1978	August 1978	May 1979
Upright Pull			
Males	134.3 6.4	140.9 5.9	143.3 6.3
Females	88.1 3.9	87.8 4.1	92.0 6.8
Upper Torso			
Males	106.6 4.7	113.9 3.7	115.8* 5.4
Females	66.8 1.9	70.5 1.9	69.3 1.5
Trunk Extensors			
Males	87.1 3.5	79.7* 3.1	86.2 3.8
Females	59.2 2.8	55.0 2.5	58.1 3.4
Leg Extensors			
Males	181.0 9.7	193.6 8.4	No Data
Females	124.2 6.7	134.5 9.4	No Data

Values expressed as $\bar{x}$ $\pm$ S.D.

* $p < 0.05$

Table 5. Time Lost Due To Illness/Injury.

Subject	Illness/Injury	Time Lost
Females		
1612	pelvic pain	1 wk
1626	lower back pain	2 wks
1628	none	-
1629	tendonitis	2 wks
1638	flu	4 days
1650	none	-
1659	stress fracture	6 wks
Males		
1614	none	-
1616	sprained ankle	3 wks
1620	none	-
1624	none	-
1640	none	-
1654	none	-
1656	stretched ligaments (shoulder)	3 wks
1657	none	-
1662	none	-
1665	none	-
1668	none	-

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 Use of Volunteers in Research.

LME