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There has long been concern that the resistance of some aircraft controls is too large. Now that the Air Foce has both male and female pilots, that concern is greater. The Workload and Ergonomics Branch of AFAMRL has just completed a study of the physical strength and endurance capabilities of 61 male and 61 female subjects in a stick-controlled aircraft simulator. Additionally, 110 of these subjects completed a nine-week exercise training program to strengthen muscles used on aircraft controls. Results show weak males and weak females have similar leg strength. The arm (continued)

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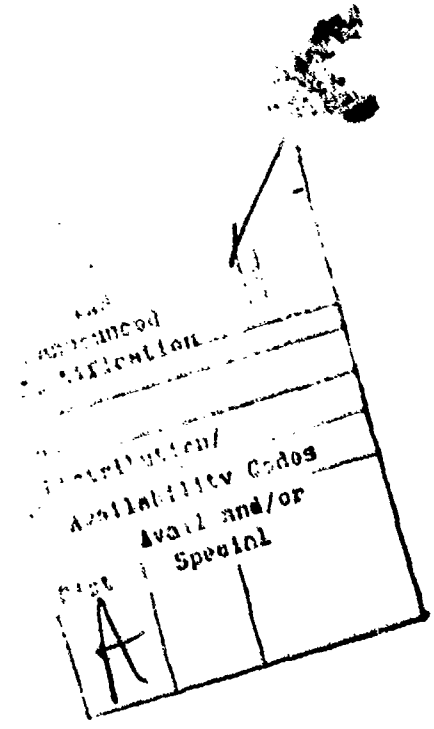
strength of strong females was similar to that of weak males, however. Physical training improved leg strength more than arm strength. Males and females had similar increases in strength due to physical training. Most of the females and some males fell below the resistance specification for current aircraft.



MALE AND FEMALE STRENGTH CAPABILITIES FOR OPERATING AIRCRAFT CONTROLS

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AFAMRL is studying the physical characteristics (size and strength) of Air Force men and women to determine their capabilities to operate existing systems and equipment and to provide design criteria for developing specifications for future systems and equipment. One of these studies is to quantify strength and endurance characteristics available to operate aircraft controls. The background and methodology for these pilot strength studies are described in a previous report (3).

The strength capabilities of women in general are less than that of men (1), and a related study by the FAA of female civilian pilots (2) indicated that some would not have sufficient strength to pilot aircraft under some conditions. Since the aircraft and specifications for aircraft are based on the physical size and strength characteristics of male pilots, there is need to investigate the accommodation of future pilots.

The objectives of this study, were (a) to measure the strength characteristics of male and female subjects for operating a stick-type aileron and elevator control and rudder pedals, (b) to determine how much increase in control performance could be achieved by a physical training program, and (c) to determine what type of physical training is most efficient for this purpose.

This study involved a combined effort at two research facilities. The strength testing was performed at AFAMRL by Dr. Joe McDaniel and Lt Col Maureen Lofberg of the Workload and Ergonomics Branch, together with Mr Michael C. Jennings of the University of Dayton Research Institute. The anthropometric measures were performed by Lt Col Lofberg (AFAMRL) and Kathleen Robinette of Anthropology Research Project, Inc. The physical training part of the program was conducted at the Department of Physical Education at the University of Dayton by Dr. Doris Drees, Dr. Robert Boyce, Mr. David Eby, and Ms. Janet Schlabach.

Sixty-one male and 61 female subjects were selected according to the stature and weight criteria for USAF pilots defined in AFR 160-43. With few exceptions, the subjects routinely participated in strenuous physical exercise.

Subjects were tested in a stick-configured cockpit instrumented with electronic force transducers and their scores recorded via a computerized data collection system. Subjects wore Nomex flying gloves and USAF flying boots during the strength tests. The data reported here represent the maximum force applied to a control during a 4-second static exertion. All exertions on the stick were with the right hand only. Endurance measures were also made, but will not be reported here.

Table 1 shows the summary results of the baseline maximum strength data, that is, measurements taken prior to the physical training (122 subjects). The 50th percentile represents the median force value. The median forces for the female were about 60 percent of the male forces. There was little overlap of strength distributions for the stick control, the weaker males (5th percentile) performing similar to the stronger females (95th percentile). The notable exception was that weaker males and weaker females showed similar performance on the rudder controls. There were no meaningfully predictive relationships between strength and anthropometric characteristics (correlations between 0 and 0.59).

TABLE 1 - MAXIMUM FORCES EXERTED ON AIRCRAFT CONTROLS (Pounds) BEFORE PHYSICAL TRAINING

Control & Direction	61 MEN Percentile			61 WOMEN Percentile		
	5th	50th	95th	5th	50th	95th
Stick Fwd	93	123	165	46	87	109
Stick Back	64	85	106	48	52	64
Stick Left	35	52	74	17	26	35
Stick Right	22	35	43	14	19	28
Left Rudder	170	450	700	160	260	460
Right Rudder	190	450	755	180	290	530

The stick cockpit used in this study is relevant for not only small aircraft, such as trainers; but also future transport aircraft such as the YC-14, YC-15 and even the CX. Each aircraft has different control resistances and failure modes. In some cases, the actual control resistance exceeds that currently allowable in the worst case forces in MIL-F-8785B, Flying Qualities of Piloted Aircraft. The data from this study suggest that this specification may not be consistent with the capabilities of pilots. Table 2 shows the percentage of subjects in this study falling below the specified maximum control resistance. Aileron right (adbuction) is the most difficult with 50 percent of the male subjects and all of the female subjects failing to exceed the 35-pound specified value.

TABLE 2 - PERCENT OF SUBJECTS WHOSE MAXIMUM FORCE WAS BELOW MIL-F-8782B DESIGN CRITERIA

Control	Criteria (Pounds)	Percent Below Criteria	
		MALES	FEMALES
Stick Fwd	75	0%	28%
Stick Back	50	0%	40%
Stick Left	35	5%	95%
Stick Right	35	50%	100%
Left Rudder	180	7%	11%
Right Rudder	180	0%	5%

After the baseline strength testing, subjects participated in a supervised exercise class three times per week for nine weeks. The subjects were split into two exercise groups: isotonic (31 males and 31 females) and isometric (30 males and 30 females). The isotonic exercise employed handles and pedals for raising weights by levers and cables. The equipment is similar to that commonly found in gyms and spas. The isometric exercises employed handles and pedals made immovable by cables attached to fixed objects. The exercises were defined to meet two criteria: first, the location, range, and direction of force must be similar to those of the aircraft controls; second, the exercise equipment must be readily available. Strength testing in the cockpit simulator was repeated after 3, 6, and 9 weeks of exercise. Of the 122 subjects beginning the study, 110 (55 males and 55 females) reported for the last test session.

Table 3 shows the effects of physical training after 0, 3, 6, and 9 weeks of exercise. Both the isometric and isotonic groups show similar increase in performance indicating one type of exercise is as good as the other. For the directions of left and right for the stick control, there was no increase due to either type of exercise for either sex. For left and right rudder pedals, there was a considerable increase for both sexes with both types of exercise. Although a larger increase was expected, the exercise program must be placed in the context of the subjects routine exercise outside of the program. The majority of these subjects were in good-to-excellent overall physical condition coming into the program. Where there were improvements due to exercise, males and females improved by the same amount. Weaker subjects benefited more from the physical training than stronger subjects.

TABLE 3. MEAN STRENGTH VALUES FOR MALE AND FEMALE SUBJECTS AFTER 0, 3, 6, 9 WEEKS OF ISOTONIC OR ISOMETRIC EXERCISES

		MALE				FEMALE			
	TYPE OF	DURATION OF PHYSICAL TRNG				DURATION OF PHYSICAL TRNG			
CONTROL	EXERCISE	0	3 wks	6 wks	9 wks	0	3 wks	6 wks	9 wks
Stick Fwd	Isometric	119	125	128	135	85	93	96	99
	Isotonic	132	129	135	142	84	88	90	86
Stick Back	Isometric	79	79	80	80	51	53	52	53
	Isotonic	91	87	92	94	52	50	50	51
Stick Left	Isometric	51	49	52	50	26	29	28	27
	Isotonic	51	54	55	56	27	28	28	28
Stick Right	Isometric	33	33	35	34	19	21	20	20
	Isotonic	35	35	36	38	20	21	20	22
Rudder Left	Isometric	402	410	438	450	277	341	363	380
	Isotonic	470	477	467	518	292	320	322	340
Rudder Right	Isometric	426	448	491	503	311	353	395	407
	Isotonic	486	518	489	558	320	327	348	373

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