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13. ABSTRACT (Maximum 200 words) To accommodate the needs of women in participating in expanded combat roles, NAWCAD is investigating the dynamic strength capabilities of small stature females (54.4 kg (120 lb) or less) to eject, support added head weight, and fly under G-stress. This study employed the NAWCAD Dynamic Flight Simulator (DFS) configured with its tactical fighter cockpit, displays, and controls. The aim was to determine whether such individuals have sufficient upper body strength to eject, sufficient cervical strength to support added weight, and the muscular endurance to perform operational and emergency high performance flight maneuvers. Within the scope of these tests, small stature females demonstrated the strength and endurance to safely fly physically strenuous missions and safely initiate ejection during sever physically taxing dynamic conditions. However, cockpit accommodation and pilot reach limits may hinder the small stature pilot during flight emergencies requiring full stick authority or ejection during flat spin and arrestment. Additionally, some small stature female pilots may not be able to properly position their heads due to a combination of inadequate restraint and lack of sufficient neck strength to read critical displays during flat spin recovery conditions and arrestment.				
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**CAPABILITIES OF SMALL STATURE WOMEN TO PERFORM OPERATIONAL FLIGHT TASKS DURING G-STRESS.** Barry S. Shender, Ph.D. Naval Air Warfare Center Aircraft Division (NAWCAD), Crew Systems Engineering Division, Patuxent River, MD, USA 20670-1906.

**INTRODUCTION:** To accommodate the needs of women in participating in expanded combat roles, NAWCAD is investigating the dynamic strength capabilities of small stature females (54.4 kg (120 lb.) or less) to eject, support added head weight, and fly under G-stress. **METHODS:** This study employed the NAWCAD Dynamic Flight Simulator (DFS) configured with its tactical fighter cockpit, displays and controls. The aim was to determine whether such individuals have sufficient upper body strength to eject, sufficient cervical strength to support added weight, and the muscular endurance to perform operational and emergency high performance flight maneuvers. Six women ( $51.3 \pm 2.8$  kg,  $156.2 \pm 5.0$  cm) volunteered to participate after undergoing informed consent and physical qualification procedures. For the ejection tasks, subjects assumed the recommended posture and pulled an instrumented "D" ring, using both one and two-hand grips, under 1g, 15s centrifuge exposures ( $\pm G_z$ ,  $\pm G_x$  and  $\pm G_y$ ) and during simulated flight conditions. Success was defined as the ability to exert a 40 lb. pull force. The effects of added head weight were assessed based on the subjects' ability to keep their heads upright and read cockpit displays while exposed to  $-G_z$ ,  $\pm G_y$ , simulated aerial combat maneuvers ( $+6G_z$  maximum) catapult ( $+G_x$ ) and arrestment ( $-G_x$ ) loads. Muscular exertion and fatigue were monitored using EMG electrodes on the neck. Three helmet/mask sets were tested, weighing 1.6 kg (3.5 lb.) (standard), 1.9 kg (4.25 lb.) and 2.3 kg (5 lb.). The latter two helmets were configured such that their centers of gravity were the same as the standard. Subjects were trained to perform three simulated flight tasks under DFS conditions, including 1 hour bombing runs, SAM avoidance (repetitive series of short turns from  $+3.6$  to  $+7.2 G_z$  lasting about 45 min), and single engine failure. The latter investigated how the need for constant control stick back pressure and rudder inputs to trim the aircraft affected flight skills, including ILS landing tasks. Performance was graded based on the deviation from training parameters in terms of G-load, altitude, airspeed, heading, controllability, kill scores and fatigue. The latter was assessed with a subjective scale. EMG (arm and shoulder) data were analyzed for RMS and frequency content changes. **RESULTS:** Women were able to eject using a two-hand grip under all G-loads ( $-5G_x$  was the most difficult). Subjects were able to eject significantly faster under dynamic conditions using the two-hand grip as compared to the one-hand grip. Subjects could read all displays under  $\pm 1G_y$ ,  $-1G_z$  and up to  $+4G_z$  loads while wearing the 2.3 kg helmet. Some  $-4G_x$  (flat spin) runs were aborted because subjects could not lift their heads. It was difficult to impossible to read lower displays under  $+4 G_x$  (catapult) or look up under  $-4G_x$ . ANOVA of EMG data during the added head weight tasks indicated significantly increased fatigue of the sternocleidomastoid muscle and effort of the trapezius muscle with increasing head weight. After the tests, some subjects reported headaches and hip discomfort (from lap restraints), but no neck pain. In addition to the expected increases in heart rate during  $+G_z$  exposures, heart rate significantly fell during  $+2$  and  $4G_x$  runs and rose during  $-2$  and  $4G_x$ . Under  $\pm 1G_y$  stress, heart rate fell as much as 15 bpm and notably heart rate did not decrease for all of the women during  $-1G_z$  runs. Even though EMG analysis indicated that over the 30 min single engine failure simulation, biceps and forearm muscular activity and fatigue were significantly increased, ANOVA results indicated few significant performance decrements. During the bombing scenario, kill rates averaged 70% and subjective fatigue ratings ranged from very slight to strong. 8 of 11 SAM avoidance sequences were completed, with two ending after the subject experienced 'Almost Loss of Consciousness' symptoms and one from fatigue. **CONCLUSIONS:** Within the scope of these tests, small stature females demonstrated the strength and endurance to safely fly physically strenuous missions and safely initiate ejection during severe physically taxing dynamic conditions. However, cockpit accommodation and pilot reach limits may hinder the small stature pilot during flight emergencies requiring full stick authority or ejection during flat spin and arrestment. Additionally, some small stature female pilots may not be able to properly position their heads due to a combination of inadequate restraint and lack of sufficient neck strength to read critical displays during flat spin recovery conditions and arrestment.

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