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THE PHYSICAL PERFORMANCE OF THE HYPERVENTILATOR

(Interim Report)

by

CPT Andree J. Lloyd, MSC

16 September 1971

UNITED STATES ARMY
MEDICAL RESEARCH AND DEVELOPMENT COMMAND

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13. ABSTRACT

The maximum voluntary endurance of an isometric muscle contraction was examined in three groups of subjects: chronic hyperventilators, a control group with voluntary hyperventilation, and a second control group. During each endurance session subjects were requested to estimate task related levels of pain on a five-point scale. Continuous surface electromyographic monitoring was made of the dominant muscle. The results indicated that individuals with a chronic hyperventilation syndrome were more efficient in the utilization of muscles during a strenuous physical task when measured by mean amplitudes of the electromyographic representation of neuromuscular activity. It was proposed that a therapeutic approach to the syndrome might incorporate strenuous exercise to the symptomatology of excessive breathing.

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Experimental Psychology Division
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*Present Address:

Department of Psychiatry
University of Oklahoma Medical Center
Oklahoma City, Oklahoma 73104

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ABSTRACT

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OBJECTIVE

To examine the performance of individuals characterized by recurrent episodes of the acute hyperventilation syndrome during maximum voluntary endurance of an isometric muscle contraction.

METHODS

Two groups of male volunteers and one group of referred hyperventilators consisting of 14 men each were asked to maintain an isometric force equal to 50% of their maximum voluntary strength. While maintaining the constant force, each subject was asked to subjectively scale the increasing intensity of pain resulting from the contraction. Surface electromyographic recordings were made on the biceps muscle. The subjects in one control group voluntarily hyperventilated for 1 minute prior to each endurance session.

SUMMARY

Although the results indicated that there was no significant difference in the mean maximum endurances of the three groups, the electromyographic analysis indicated that significantly less neuromuscular activity was required by the hyperventilators to accomplish a relatively identical task.

CONCLUSION

Although hyperventilators appear to have an aversion to physical activity, they seem to have the capacity to accomplish the task with greater efficiency. It is proposed that one therapeutic approach to the syndrome may include requiring the patient to engage in forms of strenuous exercise when symptomatology indicates a potential onset of a hyperventilation attack.

THE PHYSICAL PERFORMANCE OF THE HYPERVENTILATOR

INTRODUCTION

The skeletal muscle system, although under voluntary control, is subject to influence from generalized arousal levels of the organism (1). Shipman, et al. (2) demonstrated that with an increase in psychological stress there was a consistent increase in the muscles of both the trunk and extremities. Individuals, when subjected to overwhelming stress, frequently attempt to reduce the resulting anxiety by engaging in any one of a series of patterned defense responses. Included in the nosology of these behavior patterns is a group of disorders classified in general clinical practice as the hyperventilation syndrome. Symptomatology of a hyperventilator is widely variable and has resulted in numerous synonyms including DaCosta's syndrome, effort syndrome, and soldier's heart (3,4). All are included generally in the broader classification of psychophysiological respiratory reactions.

Hyperventilation has continued to be a serious debilitating disorder in the military environment since its early description by DaCosta (5). A recent study by Lowry (6) suggested a higher incidence in the military than in the male civilian population although this statistic is probably unreliable because of the lack of any syndrome specificity for hyperventilation in both the military and civilian diagnostic guides.

A hyperventilator is characteristically susceptible to attacks of acute anxiety marked by difficulty in breathing, palpitation of the heart, parasthesia or tingling of the extremities, and fatigue. In the military environment the symptoms frequently are associated with incidences requiring extensive physical activity. A first impression suggested that muscular activity was an aversive stimulus. The hypocapnia of overbreathing further complicates and reinforces the syndrome because of its deteriorating effect on psychomotor performance as demonstrated by Brown (7). Nevertheless, the overbreathing also produces hyperoxic conditions which should be facilitatory to strenuous physical activity.

Considerable evidence has accumulated since the work of Lippold (8) and Inman, et al (9) to demonstrate that an electromyographic (EMG) recording of a static muscle contraction is reflective of more than the level of muscle tension required to sustain the force (10). In addition to the tension necessary to maintain a static load, the EMG activity appears to be influenced by various parameters related to the individual's attitude toward the physical task. Increased levels of motivation have been demonstrated to produce a stress response under certain circumstances which created an overexpenditure of muscle activity reflected by a significant increase in EMG amplitude (11,12). Low motivation toward physical work found in individuals who exhibit the hyperventilation syndrome should produce similar results. The purpose of the present experiment was to assess the subjective maximum endurance of a relative isometric force under controlled conditions.

SUBJECTS

The subjects consisted of 42 male volunteers. Two groups, serving as controls, consisted of 14 men each and were selected from a pool of medical participants. They had recently completed basic military training, were in excellent physical condition, and volunteered to participate in psychophysiological experiments. The 14 hyperventilators were selected from basic military trainees who, through routine screening procedures, were diagnosed as chronic hyperventilators by the staff of the mental hygiene consultation clinic. The diagnoses were determined through initial interviews precipitated by a recent hyperventilation attack and through prior medical records reporting a previous history of hyperventilation difficulties. No further attempt to validate the diagnosis was made by the experimenter.

The majority of patients was referred by the clinic immediately following their initial interview. Through the cooperation of the clinic staff, most of the subjects were free from medication. Several had received drugs such as hydroxyzine, diphenhydramine, and chlordiazepoxide in a previous emergency room visit. One was administered thioridazine. Verbal reports by the subjects indicated that the two men who were prescribed librium had taken a 25 mg tablet 18 hours prior to the experiment. The remainder had not taken any of the prescribed medication within a 48 hour period. Although these compounds have evidenced significant influence on the skeletal muscle system, it was determined that the time since last ingestion was sufficient to insure its ineffectiveness with the present results.

APPARATUS

The apparatus (see Fig. 1) included an adjustable contour chair mounted to the floor. The frame, mounted in front of the chair, allowed for vertical and horizontal adjustments of the footplates. Positioned along the wall on the right side of the chair was the isometric handle mounted to allow for horizontal adjustments to accommodate varying arm lengths. The handle consisted of a piece of spring steel on which the strain gauges were mounted and wired as a Wheatstone bridge. The handle was connected to the steel bar by a ball and socket joint. The subject's grip was facilitated by coating the handle with silicone rubber and surgical tape. The bridge current, produced by an imbalance in the Wheatstone bridge through an application of force on the handle, was amplified by a low-level d.c. amplifier and recorded on an ink-writing recorder. A voltmeter calibrated in pounds and wired in parallel with the strain gauge amplifier was positioned in front of the seated subject and provided him a direct indication of his output. One of the relay-operated lights positioned above the voltmeter could be set to activate when a predetermined force was applied.

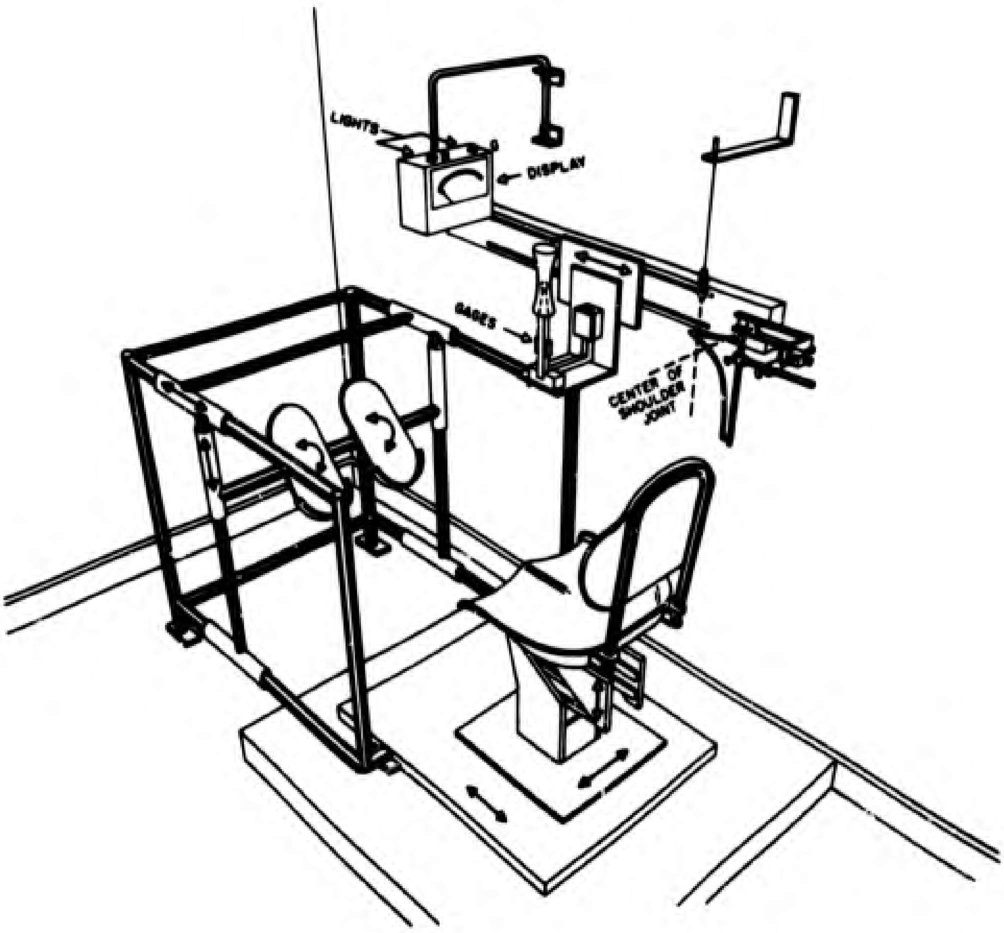

Fig. 1. Schematic of isometric apparatus.

Bipolar recordings of EMG activity were obtained with silver-silver chloride surface electrodes placed 2 in. apart and centered over the long head of the right biceps muscle. An indifferent electrode was placed on the ear lobe. The EMG activity was fed into a dynagraph recorder (Beckman Instruments) where the signals were amplified by direct d.c. couplers and further amplified to provide both an ink written record of the EMG on the polygraph and a stored record on an FM analog tape. The frequency response of the dynagraph was limited to a range of 0.16 to 200 Hz as a result of the contact modulators in the system. Tape recordings were made at 7 1/2 ips which provided accuracy within the frequency range of d.c. to 1.25 KHz. It had been determined that this restriction of frequency range was not a problem since Scott (13) found that the significant energy of a myoelectric signal recorded through subcutaneous electrodes was within a frequency range of approximately 30 to 200 Hz.

PROCEDURE

The subjects were tested in a random order. The hyperventilators referred by the clinic were informed of the general nature of the experiment. In order to prevent any malingering, it was emphasized that the procedure was not diagnostic nor would it provide any symptomatic relief. Following a brief description of the task, a signed statement of voluntary participation was requested.

After informing each subject of the general nature of the experiment, he was positioned in the chair. The isometric handle was adjusted so that while gripping the handle, the elbow angle was at 150°. The task, which was to exert a strong pull on the handle, involved elbow flexion and therefore considerable activation of the biceps muscle. The subject was instructed to keep his left arm hanging freely at his side during each trial. The footplates were adjusted to provide a leg-to-thigh angle of 150°.

The areas of the skin for electrode placement were scrubbed with 70% alcohol and scraped lightly with a hypodermic needle. The electrodes were filled with commercial electrode jelly and secured over the skin with adhesive collars. Resistance across the electrodes was never greater than 5000 ohms.

The subject was instructed to pull as hard as possible on the handle for 3 seconds. This was repeated three times with a 3-minute rest period between each pull. The greatest of the three forces was used as the subject's maximum voluntary contraction strength for that session.

Following a 5-minute rest, the subject was informed that he was to pull as long as possible at a contraction force equal to 50% of his maximum and was told what force he was to maintain on the display meter. The apparatus display lights were adjusted so that the green light would be activated at the proper force.

The subject was instructed to concentrate on the amount of pain experienced during the task and to rate the increase in pain on a five point subjective scale. The first point on the scale was defined as "just noticeable pain" while the fifth point was defined as "intolerable pain that would not permit continuing the isometric pull." An experimenter controlled event marker on the ink recorder was used to indicate the times at which the pain intensities were reported. Each subject pulled for maximum voluntary endurance twice with a 15-minute rest period between trials. This procedure was utilized for the three groups of subjects. Prior to each pull in one of the control groups, the subject was instructed to hyperventilate by increasing his respiration in deep breaths at a rate of 25/minute. This rate was continued for 1 minute prior to the start of the pull.

RESULTS

Mean cumulative endurance times for the five pain ratings of the three groups are presented in Figure 2. An analysis of variance was performed to determine the effect of the three groups and two trials on the noncumulative time for the five pain ratings. Results indicated that there was no significant difference in the endurance times of the three groups ($F = 0.99$, df 2,39, $p > .05$). A significant difference was obtained between the two trials ($F = 6.55$, df 1,39, $p < .01$) and among the five estimates ($F = 17.75$, df 4,156, $p < .01$). The interaction between these two variables was significant ($F = 5.58$, df 4,156, $p < .01$). None of the remaining interactions was statistically significant (all $p > .05$).

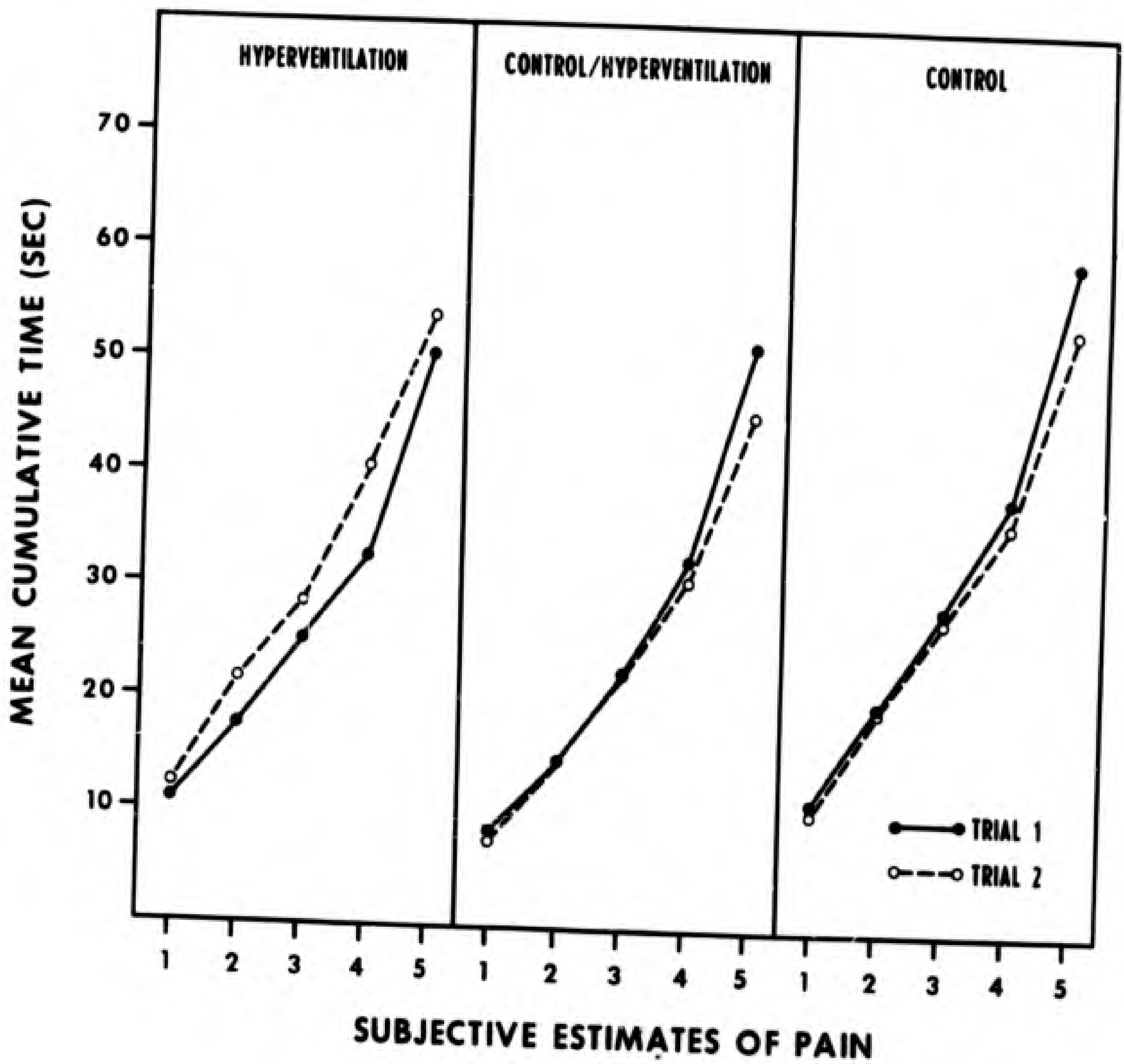

Fig. 2. Mean cumulative endurance times at which the five subjective ratings were reported for the three groups of subjects.

During each session continuous measures of EMG activity from the biceps muscles were recorded in analog form on the FM tape. An address pulse on one channel of the tape was used to provide an accurate time base during the endurance session. For statistical analyses the analog data was converted into digital format by an electronic integration of 1 second samples. The recorded EMG signal was transformed by a voltage to frequency converter, then stored in a frequency counter. The internal timing of the frequency counter provided continuous 1 second integration. The EMG values were printed and grouped into the five intervals derived from the recorded times for the five subjective judgments of increasing pain intensities. This procedure provided a basis for five means which were assumed to be subjectively equivalent points in the trials even though the maximum endurance times varied across both trials and subjects. Mean EMG amplitudes at the five estimates for the three groups are presented in Figure 3.

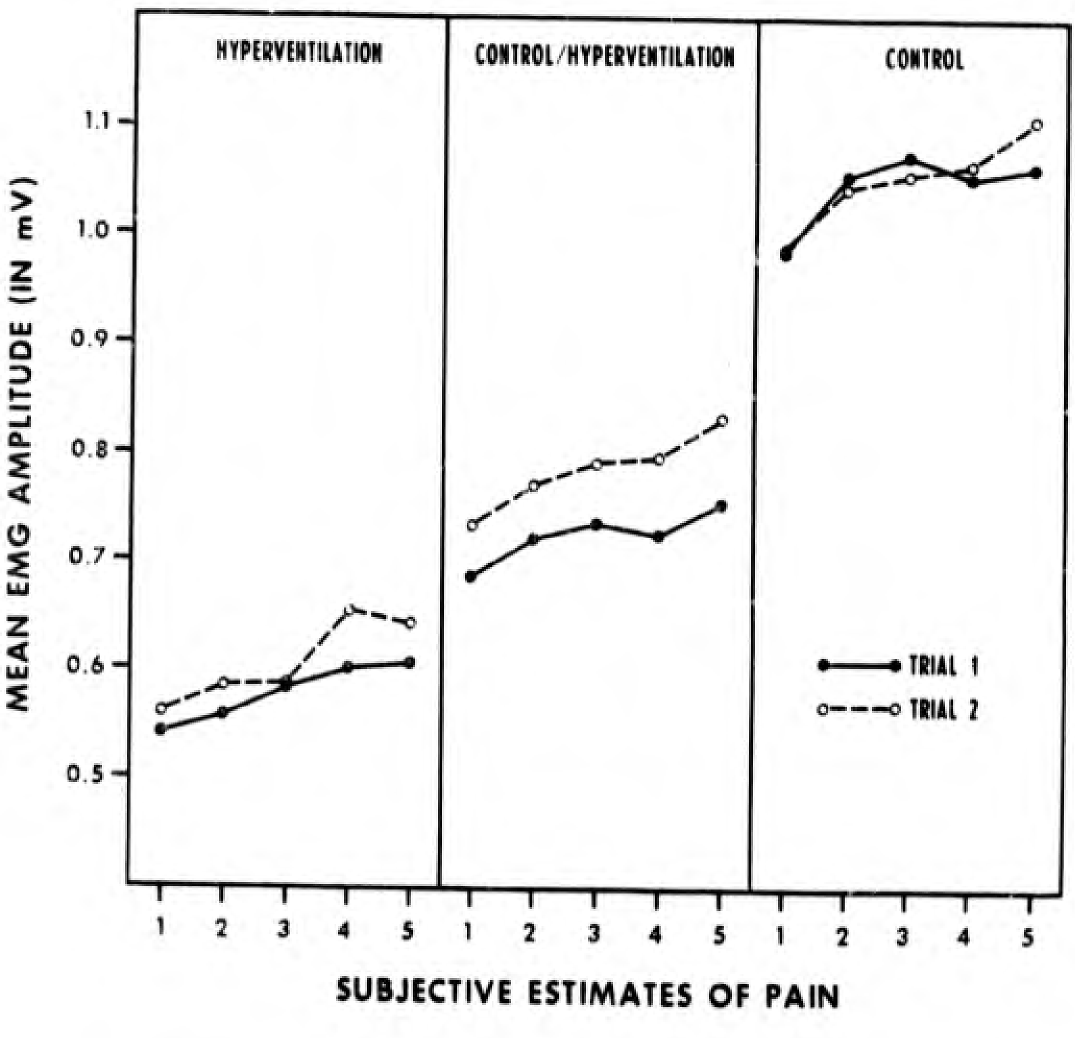

Fig. 3. Mean EMG amplitudes for the five subjective estimates of the three groups of subjects.

The mean EMG amplitudes were subjected to an analysis of variance to determine if there were any significant differences in these amplitudes among the three groups, between the two trials, or among the five intervals of subjective pain estimates. The results indicated a significant increase in EMG amplitudes of the control group from the hyperventilation groups ($F = 7.10$, df 2,39, $p < .01$). There was no difference between the trials ($F = 1.52$, df 1,39, $p > .05$) but a significant change in the amplitudes among the five estimates ($F = 10.95$, df 4,156, $p < .01$). None of the interactions was significant (all $p > .05$).

Because of the conflict between the lack of significant difference in endurance times among the three groups and significant decrease in EMG amplitudes, it was deemed necessary to analyze the actual forces sustained in the three groups. The means of the 50% maximum voluntary contractions for the three groups were 24.55 Kg for the hyperventilators, 27.60 Kg for the controls and 30.55 Kg for the hyperventilated control group. An analysis of variance and Newman-Keuls analysis, respectively, indicated a significant difference among the groups ($F = 7.22$, df 2,39, $p < .05$) with the significance produced by the mean difference between the greater force of the hyperventilated control group from the hyperventilation group ($p < .05$). There was no significant difference between the other group combinations.

DISCUSSION

In the present experiment subjects were instructed to pull on the handle at a force equal to 50% of their maximum for as long as possible. The proportional loading procedure was incorporated to reduce the inter-subject variability produced by such factors as differences in strength.

The present study indicated that the hyperventilation syndrome had no detrimental influence on the ability of a person to sustain a strenuous isometric force. Utilizing the subjective rating of pain (14), all subjects were able to estimate reliably their maximum endurance. There was evidence of initial underestimation demonstrated by the curvilinearity of the functions in Figure 2. With increased practice, the ability to estimate has been demonstrated to become more linear (15).

Several previous experiments in which two trials were incorporated in the procedure with a short rest period between indicated that recovery was not complete resulting in a reduction of maximum endurance in trial two (12). The same effect was apparent in the mean endurance times of the control groups. However, a reversal was evidenced in the hyperventilation group.

The level of neuromuscular activity reflected in the mean EMG amplitudes of Figure 3 indicated a significant reduction in muscle activity for both groups of the hyperventilated subjects. The lower EMG amplitude of the hyperventilators when compared to the hyperventilated controls may, in part, have been produced by the significant difference between the actual mean forces observed between these groups. However, differences in mean forces could not compensate for the significant difference in EMG activity between the control group and the hyperventilation group.

It has been proposed that the level of neuromuscular activity reflected in the EMG record is influenced both by physiological and psychological parameters. Amplitude increase of the EMG during an isometric endurance has been suggested to result when motor unit activity progressed from the random patterning of firing to a relatively low frequency, high amplitude synchronized pattern (16). With increased endurance the initial 50% force should theoretically increase and approach 100% as the muscle becomes fatigued. As relative force increased, a resulting minimum of partial arterial occlusion could have resulted. Humphreys and Lind (17) demonstrated complete occlusion at 70% of maximum contraction. Since it was feasible to consider that metabolic processes would have a significant long term influence on physical performance, the groups with the hyperventilation condition, either controlled or as a defense to a psychological stressor, should have the opportunity to increase their metabolic reserve prior to potential occlusion and thus facilitate their ability to sustain a strenuous contraction. Inspection of the mean endurance times of the hyperventilators provided support for this concept where there was a suggestion of greater endurance in trial two than in trial one.

The present hypothesis proposed that physical activity was stressful to hyperventilators and, when engaged, the resulting stress would result in inefficiency in performance. Inefficiency in the present task would be demonstrated by either a significant reduction in subjective endurance or by an early onset of synchronization and mean amplitude increase of the EMG resulting from the increased voluntary control of muscle activity. The present study indicated that for the same voluntary endurance times hyperventilators were more efficient than the control group.

These results suggested that a simple form of immediate treatment could be provided to the hyperventilator. One of the more common techniques utilized at present is to inform the patient of the characteristics of the disorder and recommend breathing into a bag whenever they become aware of an impending attack. If this procedure is utilized by the patient, the breathing of stale air prevents the hypocapnia from occurring. Through discussions with several patients, it was determined that many did not utilize this procedure because it was frequently impractical and more important, socially embarrassing. A more positive and perhaps practical approach could be to match the stressful symptoms of excessive breathing to the proper situation. If the patient could engage in a physically strenuous exercise in anticipation of the onset of an impending attack, the increased respiration would become a proper and necessary response.

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