Effect of Wheelchair Seat Stiffness on Back Muscle Fatigue During Wheelchair Propulsion

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A Thesis
Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Arts
in the Graduate School of the
Texas Woman's University

School of Occupational Therapy

By
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Denton, Texas
May 1990

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April 3, 1990
Date

To the Dean for Graduate Studies and Research:

I am submitting herewith a thesis written by Joe Martinez entitled "Effect of Wheelchair Seat Stiffness on Back Muscle Fatigue During Wheelchair Propulsion." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Rehabilitation Technology.

Chairperson

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ABSTRACT

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The purpose of this thesis was to identify and analyze differences in back muscle activity with different seat stiffnesses during wheelchair propulsion. It was hypothesized that because the seats offered differing degrees of stability, they would require differing stabilizing efforts using back musculature by the individual. Ten normal and nine paraplegic subjects were tested on five different wheelchair seat support surfaces of differing stiffness while performing wheelchair propulsion on a stationary wheelchair ergometer. The myoelectric activity of the erector spinae muscles in the lumbar region was studied quantitatively using EMG data with surface electrodes during wheelchair propulsion over three time periods for each cushion. An EMG power spectrum analysis was employed to measure trunk muscle fatigue caused by the instability of the different wheelchair seat support surfaces. No significant differences were found in the overall fatigue pattern response of EMG muscle activity across the five cushion types within each group. In other words, no single cushion stiffness was found to be better than any other in terms of stability as measured by EMG back muscle activity. Significant differences in EMG fatigue patterns across the three work (wheelchair propulsion) periods were found within the paraplegic group, but not for the normal group. These differences in fatigue patterns found within the paraplegic subjects were significant only within each individual cushion, but not statistically significant when compared across the five cushions. Results indicate that EMG data are useful in studying changes in activity of the trunk muscles in relation to the stiffness of the seat support for the wheelchair. Furthermore, results support previous studies that no single cushion is ideal for all people with severe physical disability and that factors other than tissue pressure need to be considered in the prescription of a wheelchair cushion. It is further concluded that objective evaluation data, such as EMG analyses, and clinical assessment combined together provide a more effective means for individualized cushion prescription.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

The wheelchair serves a dual purpose to the wheelchair bound individual. It serves as a means of transport for daily mobility and as a chair which could be used for work as well as for rest. Because the wheelchair bound person spends a majority of his or her time in the wheelchair, the design of the wheelchair, including armrests, back support, and seat surface, is important for the individual's comfort as well as performance.

Wheelchair cushions are often employed to alleviate complaints of discomfort or for prevention of pressure sores, depending on the type and degree of disability of the person. There are many commercially available cushions and selecting a wheelchair cushion for an individual with a physical disability can be a difficult task for the therapist (Garber, 1979). The therapist needs to be aware of the factors that influence the selection of a wheelchair cushion.

Studies have shown that the trunk muscles play an important role in optimization of wheelchair propulsion and function (Sanderson & Sommer, 1985). The stiffness of the cushion tends to have a direct effect on the deformation of the support surface, which would affect the position of the trunk (Brown & Pearcy, 1986). In this study, the functional relationship between seat surface stiffness and back muscle electromyographic (EMG) activity during wheelchair propulsion was investigated in normal subjects and in spinal cord injured paraplegics.

Purpose of the study

The purpose of this study was to identify and analyze differences in back muscle activity using EMG data of subjects on different seat stiffnesses during wheelchair propulsion. For this study, the EMG activity of the left and right erector spinae muscles at the L3 level was measured in relation to the seat surface stiffness during wheelchair propulsion. The hypotheses (Null) tested were:

1. There will be no significant differences in back muscle activity in normal subjects during wheelchair propulsion on five different seat surface stiffnesses.

2. There will be no significant differences in back muscle activity in paraplegic subjects during wheelchair propulsion on five different seat surface stiffnesses.

3. There will be no significant differences in back muscle activity between normal and paraplegic subjects during wheelchair propulsion on each of the five different seat surface stiffnesses.

al (1974) and Sanderson et al (1985) indicated that trunk movement or trunk position will influence myoelectric activity of several back muscles. Brown & Pearcy (1986) reported that a change in stiffness of a cushion will result in a dramatic change in pressure distribution which will cause a change in trunk position. Ross & Brubaker (1984) reported that muscle function during wheelchair propulsion plays a major role in determining propulsion efficiency and ease of handling. They also stated that EMG analysis is a definitive procedure for determining muscle activity during motion.

Research regarding the influence of fatigue on the normal EMG has been reported by investigators such as Kadefors, Kasier, Petersen (1968). The literature review in EMG studies of trunk muscles identified areas of controversy and areas in which knowledge is insufficient. The method of evaluation of myoelectric signals that has been used to analyze localized muscle fatigue in this study is the power spectrum analysis which yields information about the distribution of signal power in different frequency bands. This approach is based on the fact that the frequency spectrum of the myoelectric signal detected with surface electrodes changes in a systematic fashion during sustained contractions (Kadefors et al., 1968; Roy, Casavant, Gilmore, DeLuca, 1987). High frequency components decrease in amplitude, while low-frequency components increase. Results from these studies indicate that there is an obvious relation between the myoelectric activity and the fatigue produced by a posture or an external load. An increased signal amplitude indicates an increased rate of fatigue.

Evaluating and prescribing the optimal seating surface for the spinal cord injured person to reduce the risk of pressure sores has been a long standing field of rehabilitation research (Garber & Krouskop, 1984; Robertson & Shah, 1981; Brown et al., 1986; Garber & Krouskop, 1982). As a result numerous new products have been developed that when used properly, effectively redistribute forces from around the bony prominences (Krouskop, Williams, Noble & Brown, 1986). However, many of the wheelchair cushions that are effective for pressure relief do not provide a stable surface from which to transfer or perform functional activities.

The wheelchair cushion should aid with pressure relief and help provide stability, balance, and comfort to the wheelchair bound person (Garber, 1985). In some settings, occupational therapists are responsible for prescribing wheelchair cushions or constructing a custom-made cushion. There are many commercially available wheelchair cushions and foams used for constructing cushions. Several factors influence the selection of wheelchair cushions such as diagnosis, body build, activity level, occupations, and life style of the patient (Garber, 1979). This indicates that the therapist needs to have a knowledge of the different seat devices and materials used and the biomechanical advantages or disadvantages these cushions provide. This could help determine what is the most appropriate seat support or seat stiffness for a particular patient for optimal comfort and wheelchair performance.

In recent years new concepts have been incorporated into the design of wheelchair air filled cushions which help decrease "bottoming out" under conditions of uneven loading and have made these devices more effective in redistributing weight. The air filled cushion attempts to provide improved trunk stability for persons with high spinal cord injuries, while allowing air circulation at the seat and body interface to aid moisture and temperature control. The innovative designs and light weight of these cushions have made the air cushion a popular alternative to cushions fabricated from polymeric foams. However, even the new generation of air filled cushions present several problems that limit their practicality and effectiveness (Barbenel, 1984). Problems that affect air filled cushions relate to maintaining the correct amount of air which needs to be checked on a daily basis for optimal suspension. Inflation pressures between 30 and 35 mmhg provide pressure relief performance that is close to optimal for most users (Barbenel, 1984). However, when the cushion is inflated to such a pressure it may produce an unstable seat that reduces postural support which over an extended period of time could contribute to problems such as scoliosis or other deformities that further limit functional control and mobility.

The trunk muscles maintain balance and stability of wheelchair patients. In order to maintain trunk stability, muscular activity is necessary to counterbalance gravitational forces (Ortengren et al., 1977). Traumatic spinal cord injury can result in total or partial loss of function below the level of injury to the cord. The spinal cord injured person will lack some trunk control, depending on the level of injury. Therefore, evaluation of trunk muscles could be helpful in prescribing an appropriate wheelchair cushion for the spinal cord injured person. Postural instability due to an inappropriate seat support surface could cause increased back muscle effort in attempting to maintain balance. This could lead to muscle fatigue which would affect functional control and wheelchair propulsion effort. Results from this study will add to the information that clinicians need to consider in selecting a wheelchair cushion for persons with physical disabilities.

CHAPTER III

METHODS

Subjects

The investigation was performed on nine male paraplegics with spinal cord injuries ranging from T3 to T12 who were recruited from in-patient/out-patient clinics at The Institute for Rehabilitation and Research. Their ages ranged from 21 to 46 years, with a mean age of 33 years. The length of time from injury ranged from recent onset (less than one year) to greater than two years with the majority being greater than two years. Ten healthy normal subjects consisting of both males and females ages 21 to 50 years, with a mean age of 32 years, were also tested. Normal subjects were screened by inquiry to be certain of no history of back injury.

Experimental chair

The stationary wheelchair ergometer used in this study is shown in figure 1. The wheelchair ergometer was constructed by positioning and securing a standard wheelchair on a wooden base so that the main wheels were slightly off the floor to allow the wheels to rotate freely and permit simulation of wheelchair propulsion. The base was constructed in a manner to maintain original wheelchair

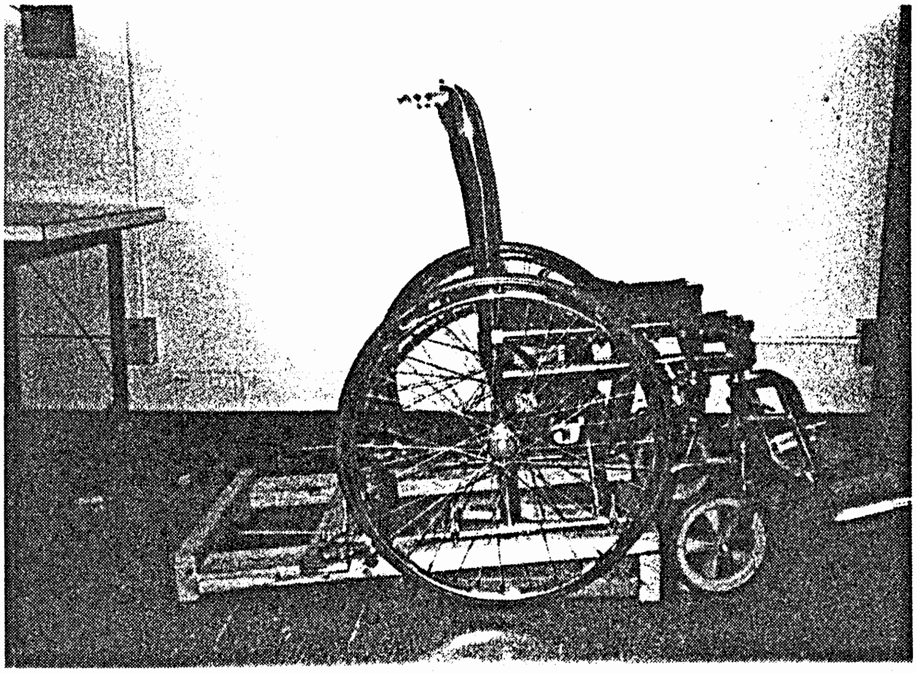

FIG. 1. Photograph of stationary wheelchair ergometer.

angle. A mechanical braking system was also attached to each main wheel to provide a moderate resistance against propulsion effort. The effect of the seat on the muscle activity was found to be accentuated when subjects propelled the manual wheelchair against a moderate resistance. In this way, the data could be collected in a shorter time period while at the same time providing close simulation of wheel resistance from ground surface.

EMG instrumentation

Two silver-silver chloride bipolar surface electrodes 1 centimeter in diameter were employed to amplify EMG signals with differential AC preamplifiers. The 1 centimeter gap under the discs was filled with electrode jelly and the electrodes were secured to the skin with hypoallergenic tape. The amplifier input impedance was 2MΩ, where skin impedance was less than 50KΩ (Winter, 1980; Seroussi and Pope, 1987). The amplifiers were battery-powered and cables were kept short (about 1 meter) and shielded to minimize interference from hum. A common ground electrode was placed mid-scapula on the surface of the spine.

The raw EMG signals were digitally processed in near real-time under control of a Compaq microcomputer with a 12-bit analog-to-digital converter. Software written in assembly language and compiled BASIC was used to sample the two channels at 500 hertz for 2 seconds (1024 points/channel). Appropriate filtering was used to prevent aliasing effects. Digital data were stored on data cartridge tape for later analysis.

Recording procedure

The data acquisition system for this study is shown in figure 2. In a laboratory setting at The Institute for Rehabilitation and Research, the subjects were acquainted with the equipment and to the test procedures. Each subject was asked to sit in a standard wheelchair alternately on five different seat support surfaces of differing stiffness. The Indentation Load Deflection (ILD) stiffness for each wheelchair cushion was measured with the ILD measurement apparatus. The ILD test procedure is a method used to measure the resistance of a material to an indenter. The force required for 25% compression of each cushion was measured and this force value is the 25% ILD. This allowed for an objective measurement of cushion stiffness. The surfaces included a standard wheelchair sling seat, Jay cushion with a 25% ILD rating of 41 pounds, Highfloat foam cushion with a 25% ILD rating of 16 pounds, Roho cushion with a 25% ILD rating of 23 pounds inflated to minimize the interface pressures between cushion and buttocks, and the same Roho cushion with a 25% ILD rating of 26 pounds over-inflated by 10 mmhg. A Texas Interface Pressure Evaluator (TIPE) was used to monitor the interface pressures and to

FIG. 2. Photograph of testing equipment with subject positioned for data acquistion.

control the internal air pressure of the Roho cushion (Garber, Krouskop, Carter, 1978).

The order of the seat surfaces was randomly assigned for testing. The same standard wheelchair was used for all data collection. The armrests were removed from the wheelchair and the subjects were instructed to lean slightly forward while propelling the wheelchair. This posture caused the back/hip angle to be at 90 degrees (Fig. 2).

With the subject in relaxed sitting position the spinous processes were marked and the exact sites for the electrodes were determined. The level of the back was defined according to the level of the palpable part of a spinous process. Each subject had one surface electrode attached to the right and one to the left erector spinae muscles (ESM) in the lumbar region at L3 level. The skin on the back was cleaned with isopropyl alcohol prior to electrode placement. The surface electrodes were placed and secured with hypoallergenic tape over the ESM at the L3 level 3 centimeters lateral to the midline and parallel to the spine (Fig. 3). Surface electrodes were used in this study to minimize invasiveness. Also, activity emanating from greater muscle volume could be observed better than would have been possible with needle electrodes (Kondraske, Deivanayagam, Carmichael, Mayer, Mooney, 1987).

For each data collection session, the subject was

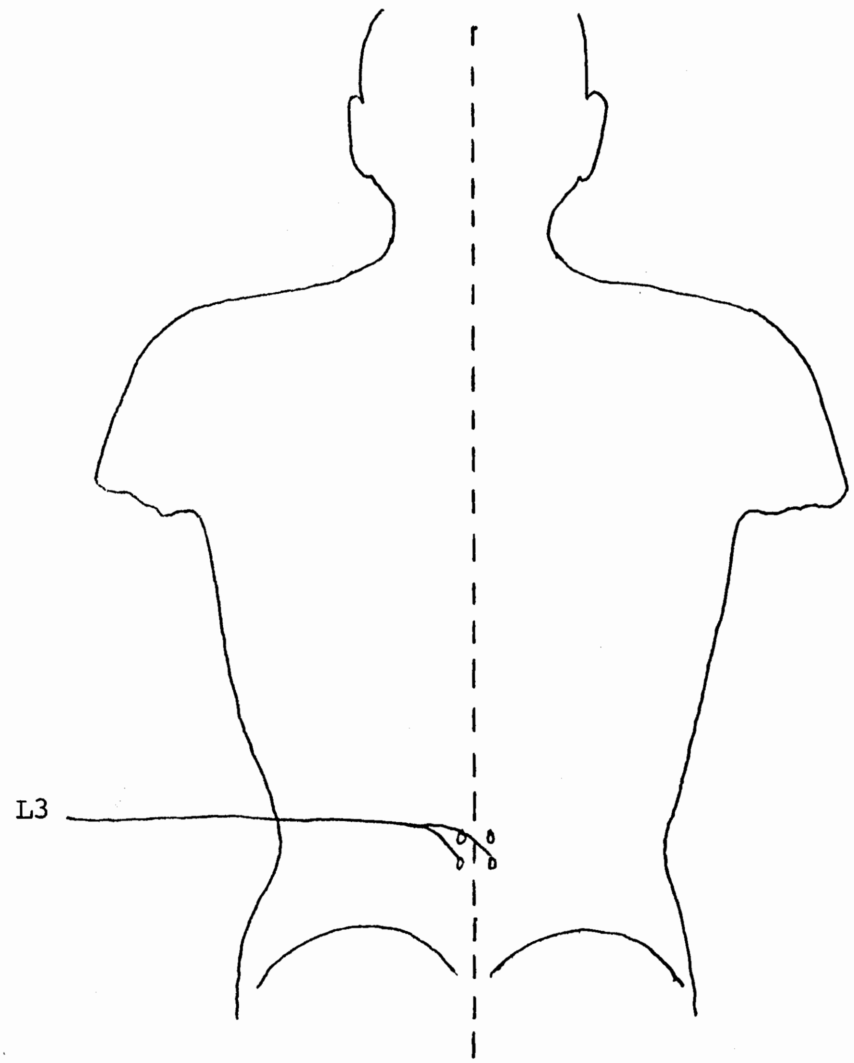

FIG. 3. Location of electrodes

seated on one of the wheelchair seats and asked to propel the wheelchair for 90 seconds (work) and then rest for 15 seconds. This procedure was performed for approximately six minutes during which time back muscle EMG activity was recorded for each work and rest period. The procedure consisted of an EMG baseline recording, three work period recordings (propelling the wheelchair), and three rest recordings. During each second work period the subject was asked to stop propelling the wheelchair at approximately midpoint and reach forward twice with each arm as in placing or grasping an object from a table. The subject would then resume wheelchair propulsion for the remainder of the 90 second work period. Between each cushion testing session the subjects were given 5-10 minute rest periods.

Data analysis procedure

The method of evaluation of the myoelectric signals used for this study was power spectral density (PSD) analysis which yields information about the distribution of signal power in different frequency bands. This method has been used by several investigators to study localized muscle fatigue, and is based on the observation that the power spectrum shifts toward lower frequencies during strong, fatiguing contractions (Ortengren et al., 1977; Eberstein & Beattie, 1985; Chaffin, 1973; Kondraske et al., 1987; and Kadefors et al., 1968). Figures 4, 5, 6 show typical EMG

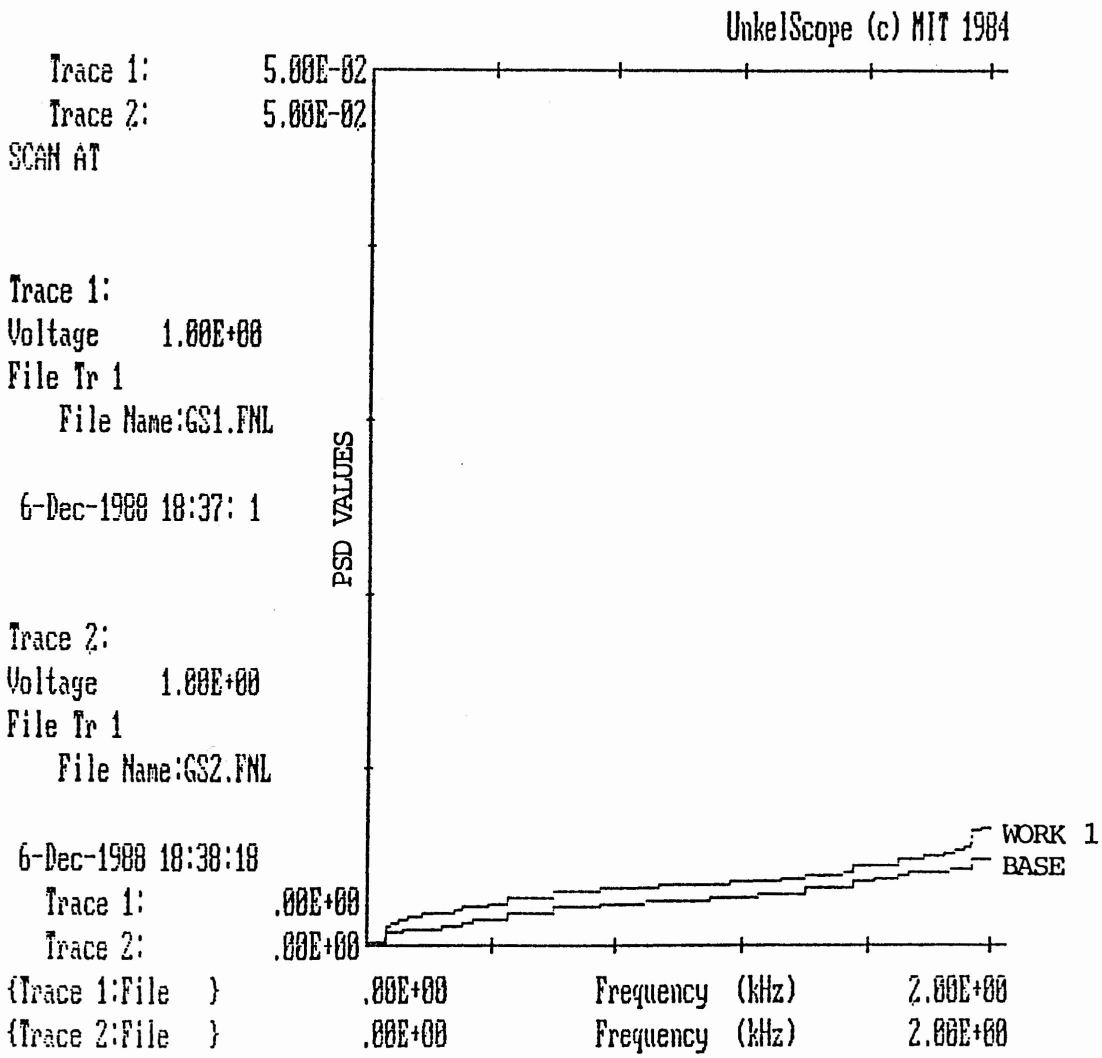

Fig. 4. EMG data showing fatigue patterns for a particular cushion on a subject. For the purpose of this study, work is defined as the time of wheelchair propulsion.

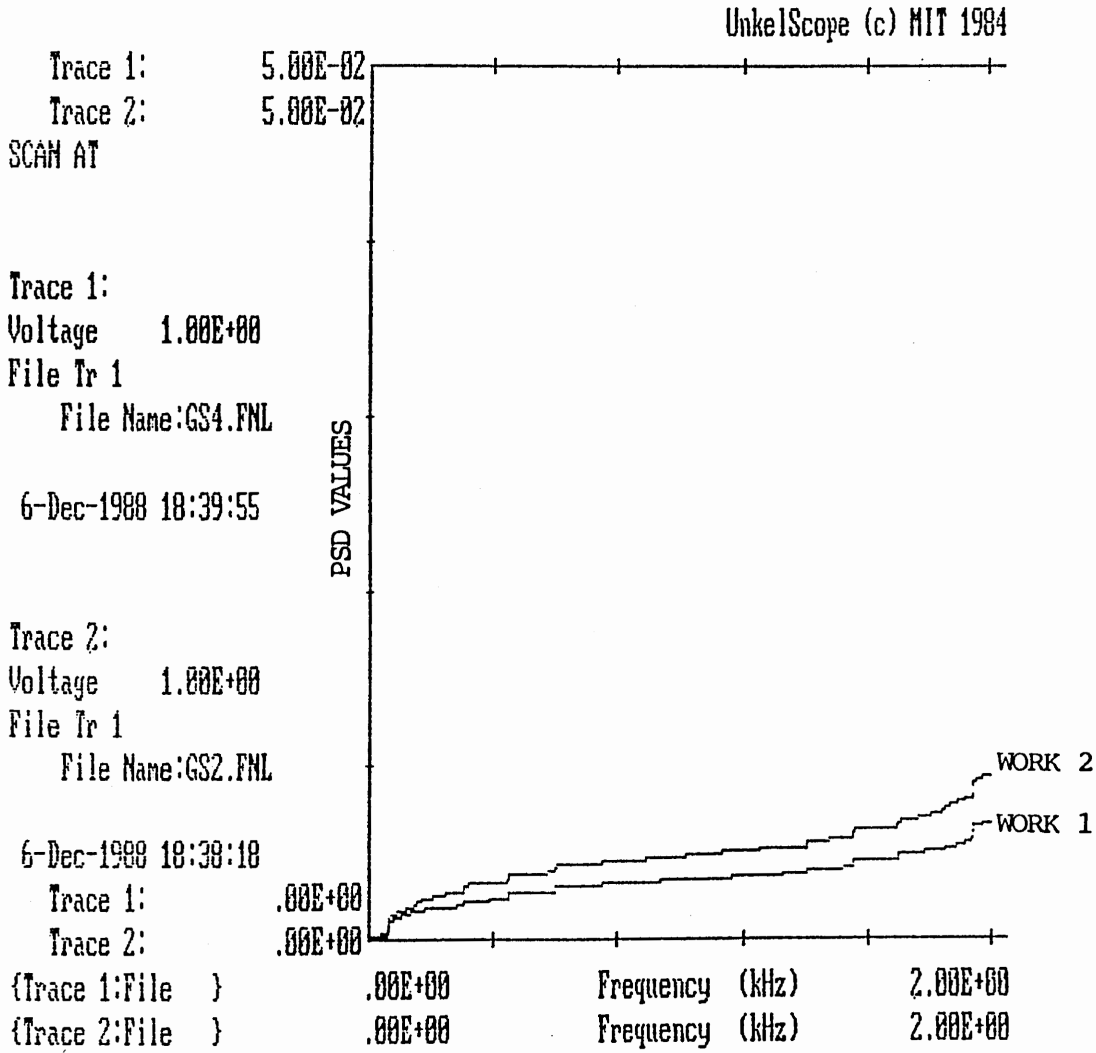

Fig. 5. EMG spectrum shift from work 1 to work 2. Note on the EMG spectrum that most of the signal is concentrated in the band between 100 and 500HZ.

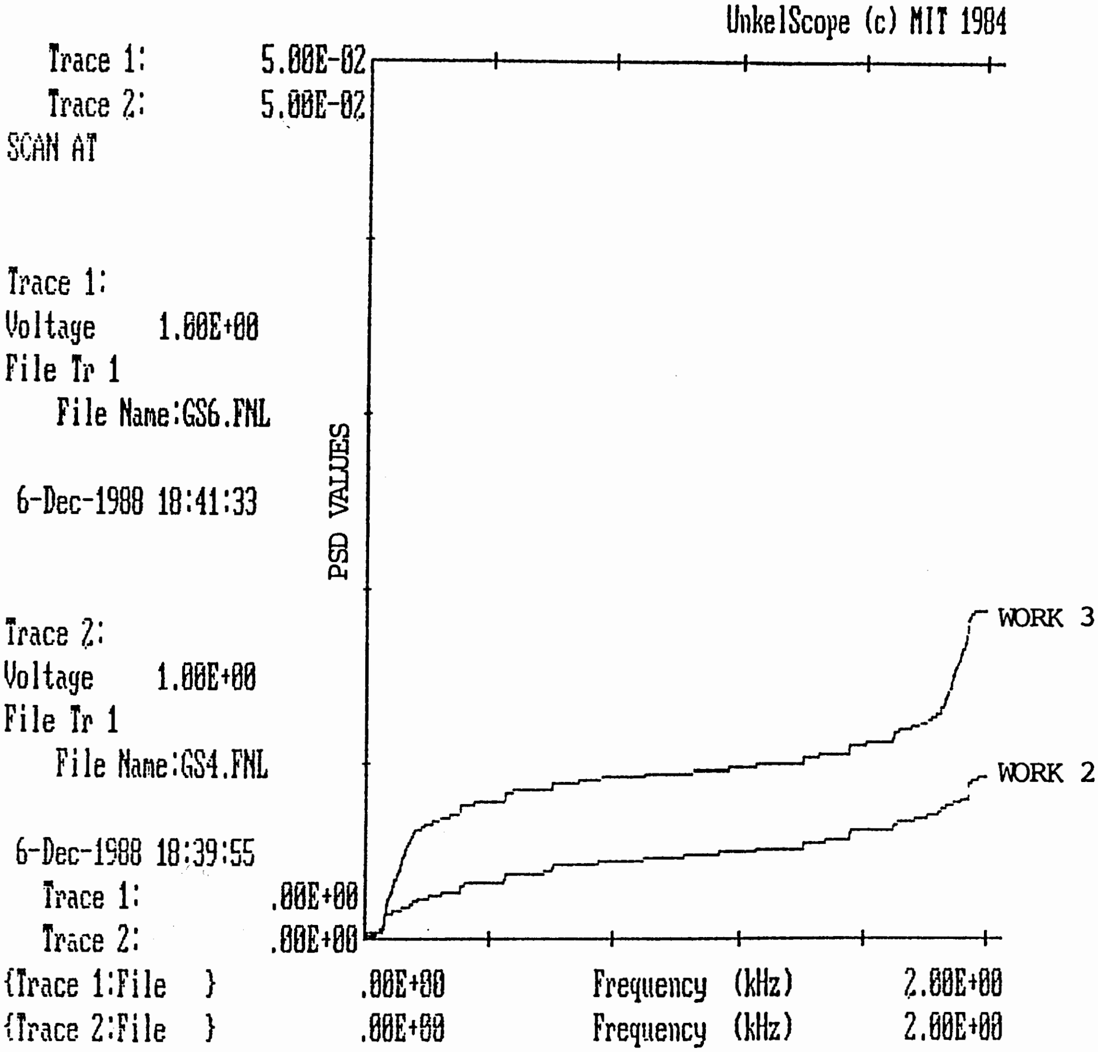

Fig. 6. EMG spectrum shift for final work period. High-frequency components decrease in amplitude, while low-frequency components increase.

spectrum shifts as recorded for this study to display the functional relation between seat surface stiffness and trunk muscle activity (in terms of fatigue patterns) during wheelchair propulsion.

A Compaq 386 computer and UNKELSCOPE software (Unkel Software Inc., 1985) were used to provide statistical processing of all raw EMG data. Data records were first processed through digital filtering operations using a second order Butterworth high pass filter set at 70 hertz. This result was transformed to the frequency domain with the aid of the Fast Fourier Transform (FFT), from which the magnitude was computed to generate the power spectral density (PSD). A function of integration of the signal was then applied which yielded a running sum of the frequency components. This process was repeated on all EMG data records. Figure 7 shows an example of a processed EMG signal for a subject on a particular cushion. Lastly, the data records were plotted to obtain digital values for statistical analysis.

Analysis of variance and covariance with repeated measures were employed for statistical analysis. Group means and standard deviations are also reported. The .05 level of significance was used.

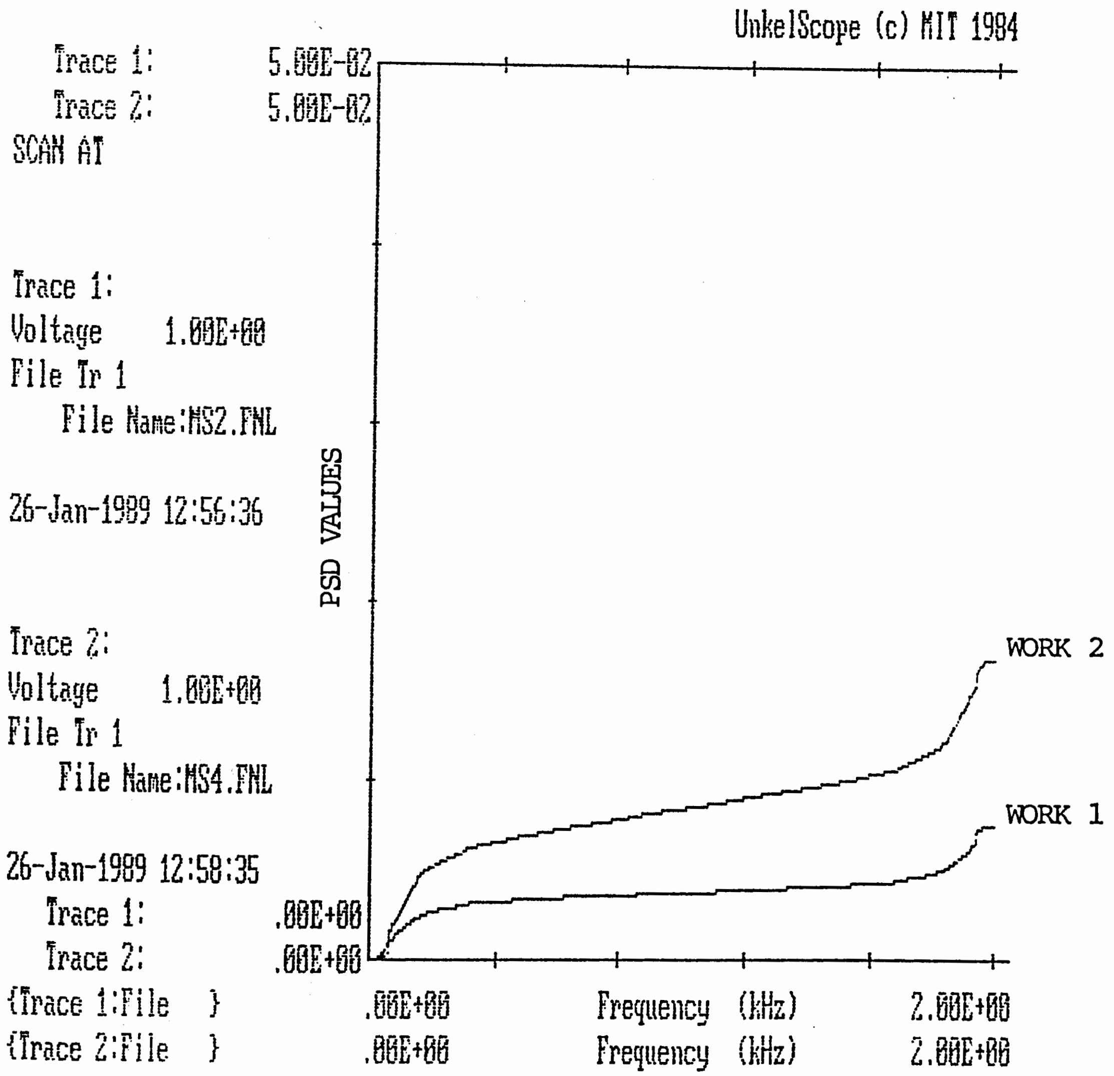

FIG. 7. Processed EMG signal for right ESM on a Paraplegic subject on the sling seat support showing changes in fatigue patterns from work 1 to work 2. The vertical trace is the magnitude of the power spectral density (PSD). In this case, the relative value of the running sum. The higher PSD value indicates a higher fatigue pattern (spectrum shift to low frequency components).

CHAPTER IV

RESULTS AND DISCUSSION

Calculations of the means and standard deviations of the myoelectric activity recorded over the three work (wheelchair propulsion) periods for the five cushion types are shown in tables 1.a and 2.a for the paraplegics and normal subjects, respectively. Figure 8 further illustrates in graphic form the pattern responses for mean myoelectric activity in relation to different cushion stiffnesses over the three work (wheelchair propulsion) periods for both groups. With the exception of the sling support, the normal subjects show a progressive decrease in fatigue pattern responses over the three work periods within each cushion as compared to the paraplegic subjects. The fatigue pattern responses seen in the paraplegic group for each cushion (except for the sling support) can be described as a quadratic configuration where the middle point is high or low compared to the other two points (Fig.8). This quadratic trend seen as a "V" shape indicates that the paraplegic subjects reveal some instability at onset of work period one, during work period two they accommodate to the instability, and then finally at work level three muscle fatigue increases again. This observation may have been a

TABLE 1.a EMG Analysis of Trunk Muscle Activity for Paraplegics on Five Cushion Types (N=9)

CUSHION	*WORK PERIOD	MEAN	SD
Sling	1	.00631	.00389
---	2	.00700	.00424
---	3	.00779	.00565
Highfloat	1	.00772	.00402
---	2	.00669	.00478
---	3	.00799	.00474
Jay	1	.00856	.00603
---	2	.00702	.00424
---	3	.00813	.00672
Roho	1	.00738	.00357
(properly inflated)	2	.00689	.00445
---	3	.00778	.00412
Roho	1	.00676	.00541
(over-inflated)	2	.00599	.00471
---	3	.00849	.00418

*Work period is the time during propulsion on a stationary wheelchair ergometer during three work periods.

TABLE 2.a EMG Analysis of Trunk Muscle Activity for Normal Subjects on Five Cushion Types (N=10)

CUSHION	*WORK PERIOD	MEAN	SD
Sling	1	.00574	.00493
---	2	.00583	.00387
---	3	.01051	.01203
Highfloat	1	.01123	.00892
---	2	.01042	.00685
---	3	.01116	.00763
Jay	1	.00915	.00766
---	2	.00818	.00756
---	3	.00675	.00652
Roho	1	.01094	.00837
(properly inflated)	2	.01023	.00627
---	3	.00931	.00507
Roho	1	.00962	.00766
(over-inflated)	2	.00959	.00747
---	3	.00853	.00654

*Work period is the time during propulsion on a stationary wheelchair ergometer during three work periods.

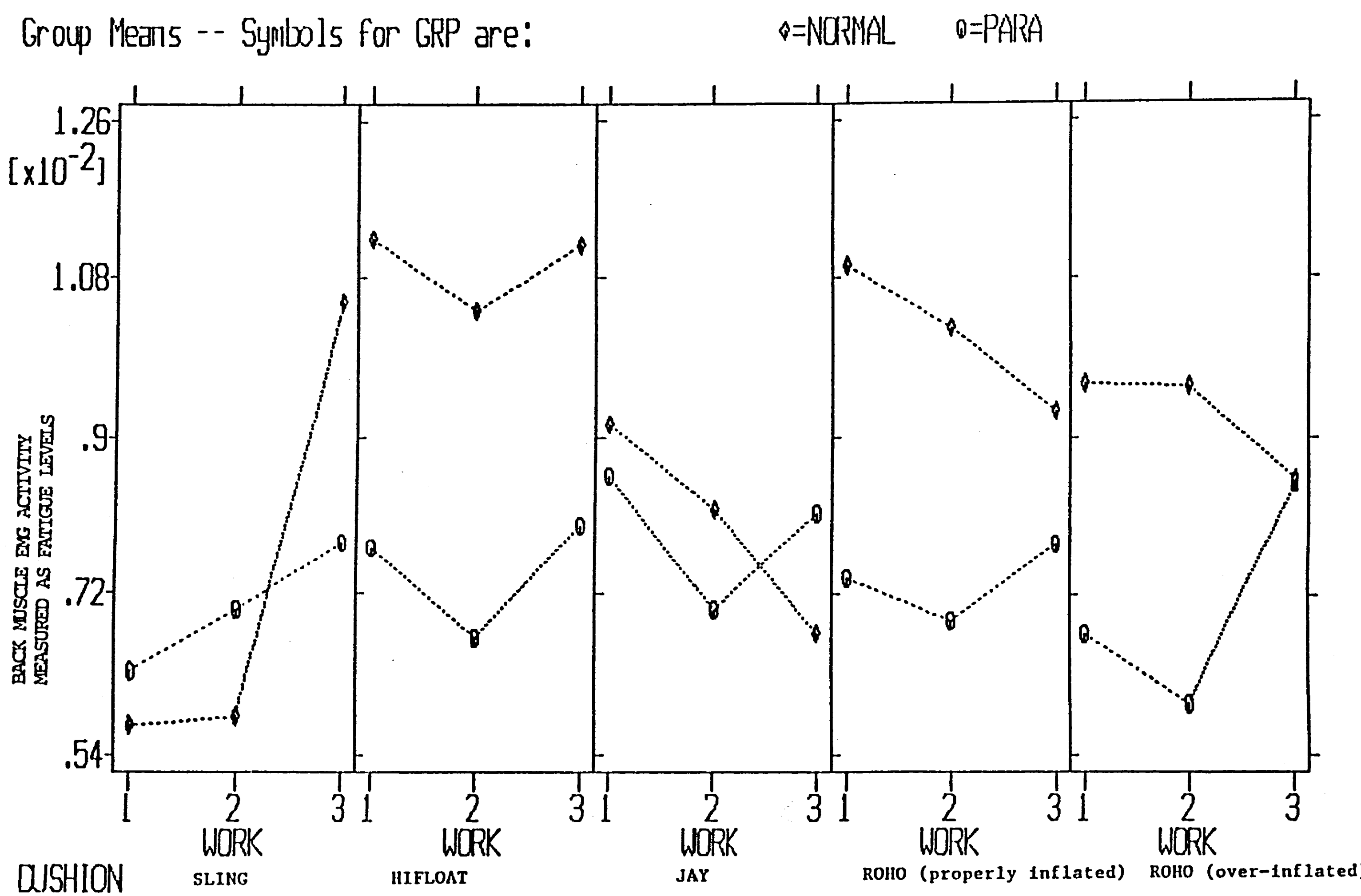

Fig. 8. Group means showing the pattern responses of back myoelectric activity in relation to the different cushion stiffnesses over the three work (wheelchair propulsion) periods. Back muscle activity is measured in terms of fatigue levels derived from the power spectral density.

result of task novelty and practice differences as well as differences in muscular strength and endurance.

In the analysis of the hypotheses being tested, the interaction of the three main factors (cushion effect, work period, and subject grouping factor) was studied. In visually inspecting the pattern response means (Fig. 8) for both groups, there appear to be significant differences within groups and between groups. However, results of a repeated measures ANOVA indicated there were no significant differences in the overall fatigue pattern response of EMG muscle activity across the five levels of cushion stiffness (with a 25% ILD range of 16#-41#) within each group. In other words there was no main effect for cushion as shown in ANOVA tables 1.b and 2.b for the paraplegic group and the normal group, respectively. Statistically, no single cushion stiffness within the 25% compression stiffness ILD range of 16#-41# as measured for this study was found to be better than the others in terms of stability as measured by EMG back muscle activity.

The repeated measures ANOVA indicated a significant interaction of work period effect with group effect for the paraplegic group (table 1.b). Consequently it was found that within the paraplegic group, there was a statistically significant difference in EMG fatigue levels across the three work periods, but only within each individual cushion.

TABLE 1.b Analysis of Variance of Paraplegic Subjects' Trunk Muscle Activity on Five Cushion Types

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	TAIL PROB.
Mean	.00733	1	.00733	31.77	.0005
Error 1	.00184	8	.00023		
Cushion Effect	.00001	4	.00000	0.22	.9233
Error 2	.00047	32	.00001		
Work Quadratic Trend	.00003	1	.00003	15.31	.0045
Work Effect	.00004	2	.00002	6.16	.0104
Error 3	.00005	16	.00000		
Interaction	.00002	8	.00000	0.49	.8603
Error 4	.00039	64	.00001		

TABLE 2.b Analysis of Variance of Normal Subjects' Trunk Muscle Activity on Five Cushion Types

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	TAIL PROB.
Mean	.01254	1	.01254	32.78	.0003
Error 1	.00344	9	.00038		
Cushion Effect	.00026	4	.00007	1.07	.3873
Error 2	.00220	36	.00006		
Work Effect	.00001	2	.00000	0.11	.8940
Error 3	.00054	18	.00003		
Interaction	.00020	8	.00002	1.48	.1784
Error 4	.00119	72	.00002		

These EMG fatigue level responses measured over the three work periods were not statistically different when compared among the five cushions or when compared to the normal subjects' fatigue level responses. In other words, the paraplegics' response to the stability of the individual cushions was essentially the same across the five cushions.

In interpreting these findings, it appears that for each seat stiffness the paraplegic group show some instability (increased fatigue level) at onset of work period one, accommodate to the instability during work period two (decreased fatigue level), but then start to fatigue again at the last work period. Although the sling support as shown in figure 8 shows a linear trend, statistically it did not make a difference. The overall pattern response mean for the paraplegic group was quadratic as seen in figure 9. In the continuous effort of trying to accommodate for the unstable posture caused by the cushion, the paraplegics show a significant differences in fatigue levels within each cushion but the differences are not statistically significant in comparing one cushion to another. Because the paraplegics already lack some trunk control due to muscular paralysis, they were unable to accommodate to the individual cushions while performing wheelchair propulsion over the three work periods; as a result, a significant difference in fatigue levels is

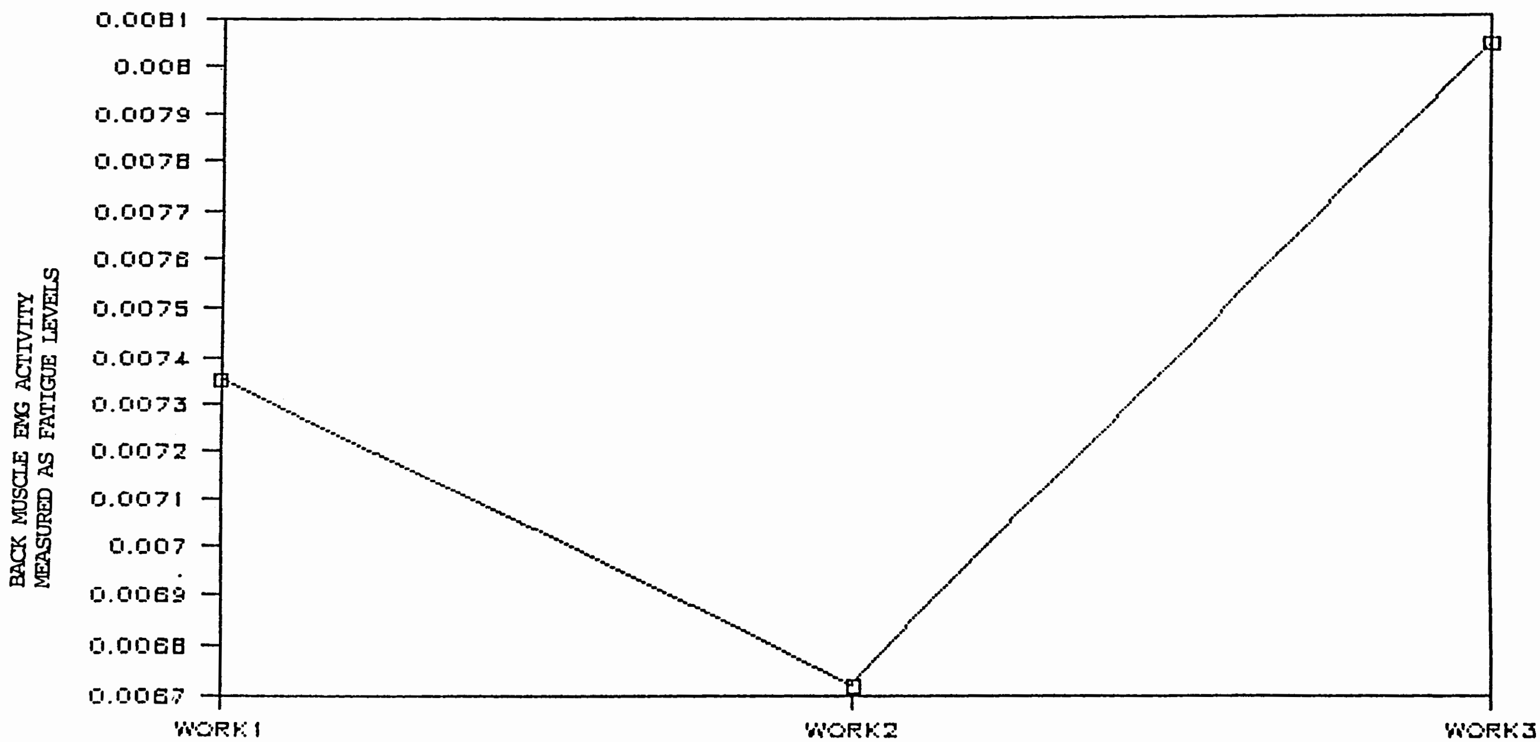

FIG. 9. The "V" shape quadratic trend is evident for the paraplegic group in looking at the overall mean response for fatigue patterns over the three work periods. (N=9)

evident.

With regard to the work period effect within the normal subjects, there were no significant differences in EMG fatigue pattern responses over the three work periods within each individual cushion (table 2.b). Although muscle fatigue patterns were evident in the EMG analysis, differences in the fatigue patterns were not found to be statistically significant. This indicates that the normal subjects had enough muscular strength and endurance to quickly accommodate to the instability of the seat support while performing wheelchair propulsion over three time periods. The pattern response for the sling support shown in figure 8 appears to be significantly different as compared to the other four cushion responses. However, statistically the fatigue pattern responses were found to be the same for all five cushions.

During data processing a slight trend towards a greater slope (increased fatigue rate) was found for right-side muscles in both groups. Figure 10 shows an example of the right side of the trunk showing a greater slope than the left side trunk muscles. However, right and left differences were not found to be statistically significant. This may be explained by differences in innervation along the muscle fibers or specific musculature function due to postural habits. The subjects' hand dominance or the type

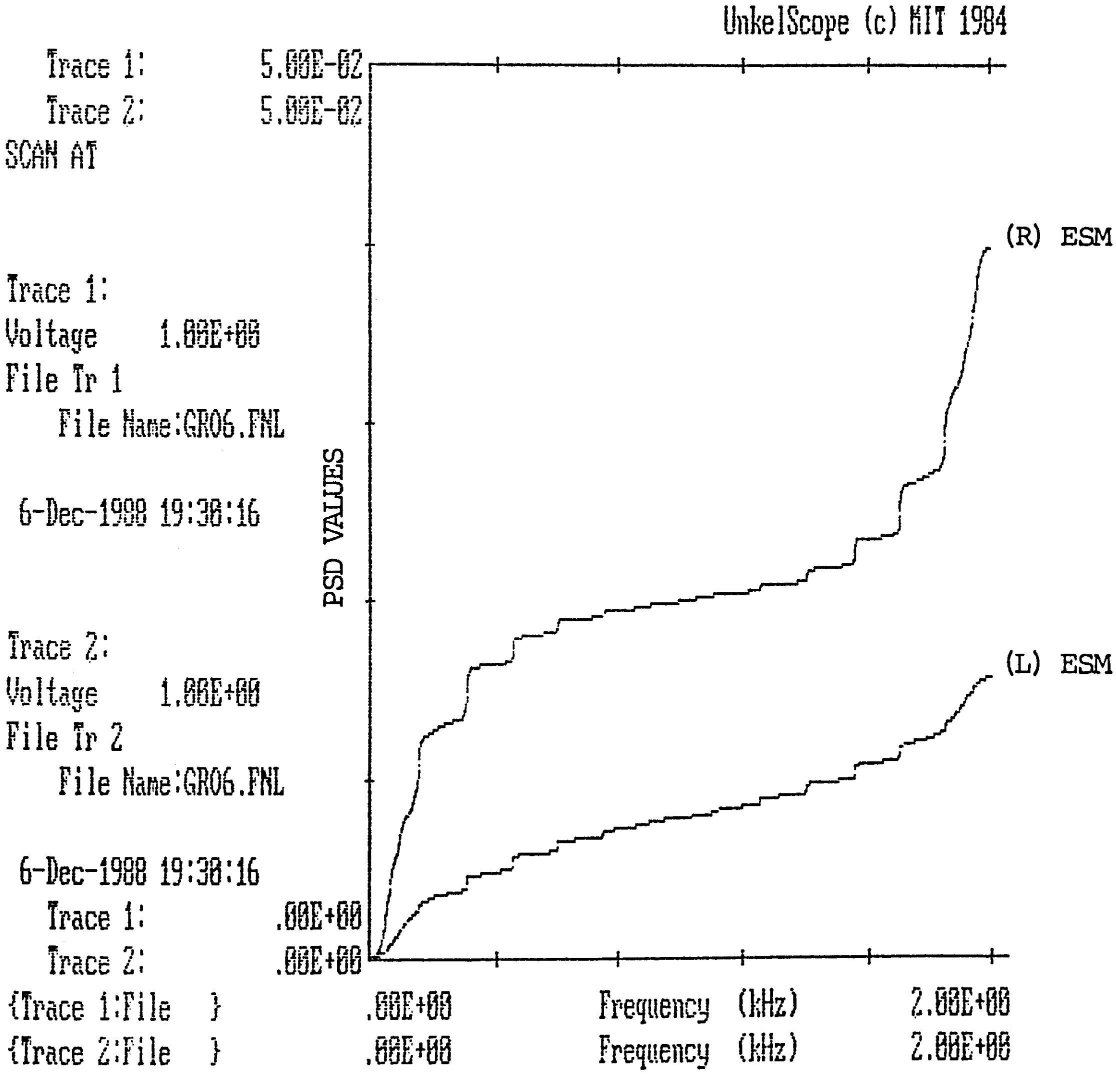

FIG. 10. Right ESM processed EMG compared to Left ESM processed EMG on the same subject.

of occupation performed prior to injury may have also been a factor. Also, differences could be due to sensitivity between power spectrum analysis and EMG averaged values (Andersson et al.,1974). The basis for this is not completely clear. However, the fact that no significant differences in myoelectric activity were recorded between the right and left side of the trunk muscles supports previous findings by other researchers (Jonsson, 1970; Andersson et al., 1974). Since both sides were theoretically contributing to force output, and no significant differences were recorded between the right and left side of the trunk, right and left side measures were averaged to produce single results. Within the limits and similarities of the sample obtained, age, sex, weight, and height did not appear to be significant.

Although no statistically significant differences in muscle fatigue were found across the five cushions for both groups, the paraplegic subjects performed better in terms of least to highest muscle fatigue in the following order: The Roho cushion properly inflated to minimize interface pressures, followed by the Jay cushion, Highfloat cushion, Roho (over-inflated by 10mmhg), and then the sling support. In paraplegic subjects who had considerable mobility, sensations of decreased stability and impaired transferability were commonly reported with the Roho cushion. This could be based on the fact that the Roho cushion does not provide lateral stability or maneuverability in some subjects due to the cushion's height and convex surface, although Roho cushions provide excellent pressure relief (Garber, 1985). Comments regarding the Jay cushion included ease in transferability and sensations of a stable functional posture. The Highfloat cushion reportedly provided sensations of comfort for static postures, and some trunk stability among the paraplegic subjects, but it elicited complaints of impaired transferability. The Roho over-inflated cushion was reported to be a comfortable and stable surface among the normal subjects, but just the opposite among the paraplegic subjects. The normal subjects performed better on the Jay cushion, followed by the Roho cushion (over-inflated), Roho (properly inflated), the Highfloat cushion, and then the sling support.

In this study, the functional relationship between seat surface stiffness of the wheelchair and trunk muscle activity during wheelchair propulsion was investigated using EMG data. The power spectrum analysis method was used to reflect the rate of trunk muscular fatigue caused by the stability of the seat support while attempting a functional task such as propelling a wheelchair. Data indicate that lumbar musculature fatigue rates are repeatably measurable with EMG spectral shift techniques and that this technique warrants further investigation for clinical use.

Significant findings of this study indicate that no single cushion stiffness with a 25% ILD range of 16#-41# was found to be better than the others in terms of stability as measured by EMG muscle fatigue. However, fatigue level responses measured over the three work periods were found to be statistically significant within each cushion with the paraplegic subjects. From a clinical perspective, the present results provide additional evidence that no single cushion is optimal for all people with spinal cord injury. Factors other than pressure enter into the successful prescription of an effective pressure-relief device. These findings demonstrates the importance of trunk musculature and postural stability as an important issue in wheelchair cushion prescription for patients with physical disabilities. The pressure-relief device should also provide trunk stability and a stable surface from which to transfer or perform functional activities to minimize trunk muscular fatigue. This consideration is important in order to enhance the functional potential of the patient and wheelchair performance. Since the spinal cord injured person already lacks some trunk control due to muscular paralysis, the importance of postural stability and trunk muscular fatigue is evident. These findings will help increase the knowledge base of occupational therapists regarding wheelchair cushions and the importance of individualized patient evaluation for cushion prescription. In the individual evaluation for prescribing a wheelchair cushion, it should be possible to reasonably satisfy needs both for pressure relief and for postural stability.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study, the following conclusions have been developed:

1. The analysis of EMG data is useful in studying the changes in activity of the trunk muscles in relation to the stiffness of the seat support surface for the wheelchair.
2. A useful method for evaluation of myoelectric signals that provides a means to study trunk muscle activity in terms of fatigue produced by a posture or an external load is the power spectrum analysis. The literature review and results of this study indicate that this technique warrants further investigation for clinical use.
3. Statistically, no single cushion stiffness was found to be better than the other in terms of stability as measured by EMG back muscle activity. These data provide additional evidence that no single cushion is optimal for all people with spinal cord injury.
4. Significant differences were found in the fatigue pattern responses over the three work (wheelchair propulsion) periods within each individual cushion for the paraplegic group. Since muscle fatigue is evident in relation to wheelchair seat stiffness while performing a

functional task (i.e. propelling a wheelchair), it may be beneficial to evaluate trunk muscles over time for patients prior to recommending a seat cushion to include fatigue as an important clinical consideration.

5. Some cushions were preferred over others by both groups, and clinically (but not statistically) the normal subjects performed better on some cushions with regard to muscle fatigue. These differences between cushions may warrant further evaluation and research in relation to trunk muscle fatigue and more aggressive wheelchair performance, as in wheelchair sports.

6. The fatigue pattern response for the paraplegic subjects showed a quadratic trend seen as a "V" shape. Perhaps this quadratic pattern could serve as a baseline for further research in studying trunk muscle fatigue in relation to cushion stiffness in wheelchair sports.

7. Wheelchair cushions are frequently prescribed by occupational therapists to spinal cord injured persons for prevention of pressure sores. This study demonstrates that factors such as trunk stability, ease of transfer, activities, and independence need to be considered in addition to pressure relief. Therapists who are responsible for prescribing wheelchair cushions must be familiar with the characteristics of the cushions so that rational recommendations can be made. Clinical assessments and

objective criteria provided by EMG analyses (and other instruments such as the Texas Interface Pressure Evaluator) could perhaps be more effective combined together for individualized cushion prescription.

Several recommendations were developed for future research in the area of trunk muscle activity in relation to wheelchair seat stiffness:

1. Studies are needed of whether a higher or lower ILD rating for cushions makes a difference in trunk muscle activity. Active paraplegics may benefit from using cushions with different ILD ratings for different activities such as sports or occupation.
2. Studies with longer time periods of wheelchair propulsion to illustrate trunk muscle fatigue in wheelchair sports or other physically demanding activities would be beneficial.
3. Further research is also needed to determine whether there are relationships between the stiffness of the support surface for the wheelchair, trunk muscle activity, and the development of spinal curvature and postural problems.
4. An autocorrelation analysis which yields the average muscle action potential duration could be used for a comparative study regarding fatigue patterns (detected by spectral shifts) and muscle activity changes.

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APPENDICES

APPENDIX A

Human Subjects Review
Approval Form

TEXAS WOMAN'S UNIVERSITY
HOUSTON CENTER
HUMAN SUBJECTS REVIEW COMMITTEE

APPROVAL FORM

Name of Investigator: Joe Martinez Center: Houston Campus

Address: 10610 28th St. Date: 1-4-88

Santa Fe, Texas 77510

Dear: ______

Your study entitled: Influence of Wheelchair Seat Stiffness on Back Muscle Activity During Wheelchair Propulsion

has beeen reviewed by a committee of the Human Subjects Review Committee and it appears to meet our requirements in regard to protection of the individual's rights.

Please be reminded that both the University and the Department of Health and Human Services regulations typically require that signatures indicating informed consent be obtained from all human subjects in your study. These are to be filed with the Human Subjects Review Committee Chairperson. Any exception to this requirement is noted below. Furthermore, according to HHS regulations, another review by the Committee is required if your project changes.

Any special provisions pertaining to your study are noted below:

______ Add to informed consent from: No medical service or compensation is provided to subjects by the University as a result of injury from participation in research.

______ Add to informed consent form: I UNDERSTAND THAT THE RETURN OF MY QUESTIONNAIRE CONSTITUTES MY INFORMED CONSENT TO ACT AS A SUBJECT IN THIS RESEARCH.

______ The filing of signatures of subjects with the Human Subjects Review Committee is not required.

______ Other: see attached sheet

______ No special provisions apply.

Sincerely,

William R. Gould, Ph.D., Chairperson,
Human Subjects Review Committee - Houston

2/10/88

HSRC-Houston/1987

APPENDIX B

Informed Consent

INFORMED CONSENT

I hereby give my consent to be involved in the following investigation:

(1) I understand that I will be participating in a study that is designed to evaluate how my sitting on different wheelchair seat supports affects the activity in my back muscles. During the study I will be asked to sit in a standard wheelchair alternately on four different seat supports. I will be asked to perform simulated wheelchair propulsion for approximately 45 seconds and then rest for approximately 15 seconds. This same procedure will be performed for 3 minutes during which time my back muscle activity will be monitored by placing sensors on my back, against the skin. I also understand that this procedure will be performed once for each seat support surface. The sessions will be directed by Joe Martinez, TWU graduate student.

(2) I understand that surface EMG electrodes will be placed on my back against the skin and that there is a possibility that my skin will be irritated from the electrode adhesive. I agree to have my skin inspected before and after each data collection. I also understand that if any sign of skin breakdown is noted, my participation in the study may be terminated.

(3) I understand that the results from this study will provide information that will aid clinicians when considering the selection of wheelchair seat supports for spinal cord injured persons.

(4) I understand that there are no other applicable alternative procedures available.

(5) I understand that my confidentiality will be protected through a number coding system so that my name will not appear on any data collected in this study. I further understand that the results of this study will be reported anonymously without using names of subjects.

(6) I understand that my participation in this study is done on a voluntary basis and that I am free to withdraw at any time without penalty.

(7) I understand that Texas Woman's University/The Institute for Rehabilitation and Research in Houston, Texas will provide no compensation or medical treatment related to risks associated with this study.

(8) I understand that I may contact the researcher or the research advisor at any time if I have pertinent questions and/or concerns. These persons are Joe Martinez, student researcher, at (409) 849-2447 or Dr. Jean Spencer, research advisor, at (713) 794-2131.

Signature ______________________________ Date ______________

Witness ______________________________ Date ______________