

**LABORATORY REPORT COVER PAGE**

GROUP NUMBER: T1

EXPERIMENT NUMBER: 5

TITLE: Skeletal Muscle – Electromyography

DATE SUBMITTED 9/7/00

**OVERALL GRADE 100/100****ROLE ASSIGNMENTS**

<u>ROLE</u>	<u>GROUP MEMBER</u>
FACILITATOR.....	Mina Wu
TIME & TASK KEEPER.....	Christopher Hack
SCRIBE.....	Alice Wu
PRESENTER.....	David H. Kim

**SUMMARY OF CONCLUSIONS**

Fractional clench test (Lesson 1 Biopac), incremental clench test and fatigue test (Lesson 2 Biopac) were administered to four subjects ranging in muscular development and tone. Results of the test were compared both between each subject's dominant arm and non-dominant arm, and across subjects. Analysis of results reveal that the fractional clench test was irreproducible due to factors such as lack of muscle control and fatigue. Thus, no statistical significance can be derived due to the complete lack of experimental reproducibility. Forces applied during the incremental clench test are documented in the EMG and thus it seems that motor unit recruitment versus force applied is reproducible. However, t-test between the first trials and the second trials carried indicates that they are in fact significantly different, revealing that muscular fatigue due to the first trial significantly affects the results of the second trial and making the test also irreproducible. Similar conclusion is drawn for the fatigue test: the test is affected by multiple variables, such as muscular control and concentration of the subject, making the test results essentially unpredictable.

**GOOD ABSTRACT GRADE 20/20**

**Results**

**Fig A**

		Subject 1, trial 1				Subject 4, trial 1			
		% left and right arm difference				% left and right arm difference			
Cluster No.		min	max	p-p	mean	min	max	p-p	mean
1		48.79258	7.307075	30.40114	52.24685	57.96444	91.31269	-19.60691	99.79896
2		1.128905	42.49842	19.54605	61.00984	59.84974	113.7893	74.1223	97.82089
3		-14.64966	7.71038	-63.69185	10.56927	8.328517	82.92785	75.24912	45.16478
4		18.65959	24.35323	20.95879	19.38438	1.791912	-0.027004	-89.81298	26.47582
		Subject 1, trial 2				Subject 4, trial 2			
1		61.33377	37.83075	49.40015	47.48617	3.202935	0.294436	0.618557	23.71402
2		30.87271	-17.26278	21.20539	36.2924	-3.514803	26.60355	-9.417113	24.15962
3		-7.534116	-19.11934	-12.73482	-10.4454	-18.35328	13.4281	-34.31528	-2.367103
4		-5.211416	7.340595	0.147579	-11.04934	0	0	51.51881	-11.39799

		Subject 2, trial 1				Subject 3, trial 1			
		% left and right arm difference				% left and right arm difference			
Cluster No.		min	max	p-p	mean	min	max	p-p	mean
1		21.04393	70.93084	43.64889	29.11033	-24.60159	-25.56102	-25.03569	-12.44296
2		-22.47809	-43.11135	-31.77602	-19.81734	19.87983	-26.63185	-0.412574	-29.1754
3		22.9107	-28.66984	-0.260824	-19.74095	-20.64046	-19.20363	-19.98676	-12.04071
4		5.976586	-8.070788	-1.163684	-32.64006	4.429734	15.95305	10.01221	-40.69545
		Subject 2, trial 2				Subject 3, trial 2			
1		-3.38267	26.21769	10.5905	15.81845	-56.56987	-72.14141	-64.16021	-20.68061
2		17.81238	11.68532	14.88338	-9.713705	-22.3158	-32.55403	-26.92488	-29.75186
3		15.79492	6.184771	11.34476	10.67158	-11.10659	4.748779	-2.318502	-17.44394
4		-30.96822	-7.707179	-19.67339	-23.31499	-4.932696	27.97577	12.21561	0.5389
		Subject 2, trial 3				Subject 3, trial 3			
1		9.201727	42.34772	26.08238	-10.25	1.099497	-1.957468	-0.167813	-2.245563
2		-62.05272	-16.22982	-41.22053	-29.34297	-21.99848	4	-9.59986	-35.29589
3		-9.811964	1.230683	-4.482031	6.131046	9.369178	-19.05785	-4.791303	-36.49362
4		-28.03671	-3.154449	-16.479	-33.01458	2.96562	-12.20423	-5.538108	-24.80661
		Subject 2, trial 4				Subject 3, trial 4			
1		43.33361	26.55769	34.87136	55.28638	-2.756108	-3.85659	-3.217809	9.579795
2		88.92487	4.611951	53.71045	35.64519	49.95608	51.01974	50.42159	13.60985
3		-26.17705	3.379787	-11.38596	-4.489942	52.69471	0.637528	30.58291	21.80607
4		-13.86963	-32.2285	-22.59331	-22.36584	18.88263	22.19821	20.38606	36.24532

This is the table of results for the percentage differences in the EMG readings for the two arms in Lesson 1.

**THESE ARE WILD DIFFERENCES- DID YOU TRY A THIRD TRIAL ON ANY ONE AFTER SOME REST TO SEE WHAT IS GOING ON.**

**Fig 1**

slope integrated EMG vs. force (mV / kg)					
Subject #	weight (pounds)	Named	dominant arm	other arm	% difference
1 (trial 1)	175	Chris	0.0115	0.0173	40.277778
(trial 2)			0.0196	0.025	24.215247
2	140	Dave	0.0139	0.0111	-22.4
3	115	Mina	0.0214	0.0153	-33.242507
4 (trial 1)	98	Alice	0.0286	0.0316	9.9667774

(trial 2)			0.0359	0.0469	26.570048
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For each subject, integrated EMG value was plotted against the force at peak as measured by the EMG. A linear trendline was fit to each of the plots and the slope recorded.

**Fig 2**

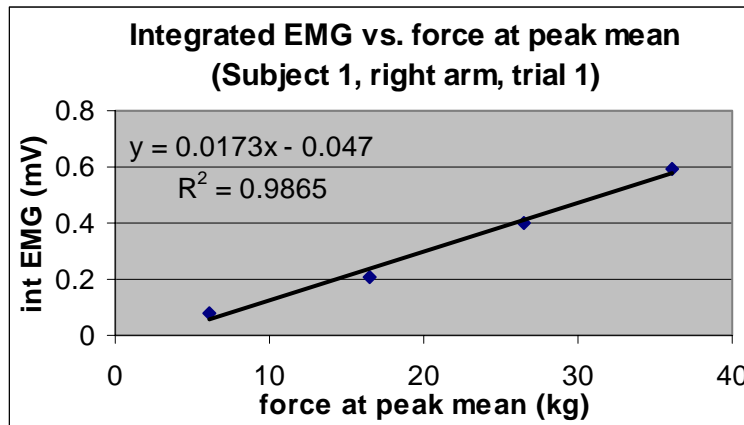
maximum force developed (kg)					
subject #	weight (pounds)	name	dominant arm	other arm	% difference
1 (trial 1)	175	Chris	43.88127	41.12767	6.47838
(trial 2)			48.19841	39.23973	20.4915
2	140	Dave	37.9581	30.62879	21.3723
3	115	Mina	20.56275	23.93771	-15.1682
4 (trial 1)	98	Alice	18.59365	16.66711	10.9274
(trial 2)			24.02932	16.06259	39.7423

Maximum force cluster on the EMG was analyzed using Biopac to determine the mean at the peak of the force.

**Fig 3**

time to fatigue (sec)					
Subject #	weight (pounds)	Name	dominant arm	other arm	% diff
1 (trial 1)	175	Chris	9.936	19.67	-65.7569
(trial 2)			20.71	13.68	40.88398
2	140	Dave	27.442	25.158	8.684411
3	115	Mina	25.05	9.41	90.77191
4 (trial 1)	98	Alice	10.97	11.98	-8.80174
(trial 2)			7.738	16.73	-73.5001

From the force versus time graph on the EMG, the magnitude of the maximum strength (at the beginning) was found and 50% force calculated. The time to reach the fifty percent force was denoted as the “time to fatigue”.

**Fig 4**

Integrated EMG vs. force at peak mean at different intervals was plotted for all trials of all subjects. A linear regression line was fitted to each curve. An example of one such graph is shown above.

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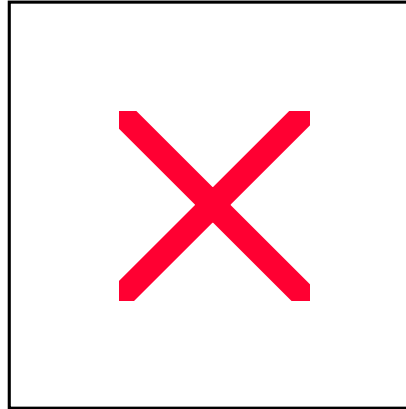
### Discussion and Conclusion

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In lesson 1, quantitative statistical proof of significance was not capable of being performed due to the several limiting factors. The first factor was the lack of repeatable trials from each subject, which severely retarded the dependability of the necessary values determined from the data. The procedure was carried out twice for all four subjects tested in this experiment, thereby yielding at least two sets of data for each subject. The whole lesson was repeated for two of the four subjects (David and Mina), thereby yielding a total of four sets of data for these two subjects. However, with two and four sets of data points ( $n=2$  and  $n=4$ ), the respective Degree of Freedom ( $n-1$ ) is 1 and 3, which will thereby yield large variances and uncertainties. Another factor, which limited the ability to establish statistical significance between two sets of data points, was the non-reproducible nature of the trials. Whenever an experiment is repeated several times to collect several trials of data points, it is expected that the controls, variables, and conditions of the experiment stays fixed for all the trials. However, due to the nature of this lab and of human physiology, many conditions and factors will vary between trials and cannot be prevented. In lesson 1, the subject is told to increase the strength of his/her clench in equal increments so that the fourth is the maximum force. This type of data is extremely difficult to reproduce with many trials because the human brain and nervous system is incapable of “remembering” the strength of the clench forces it exerted from the previous trial and repeat those forces for subsequent trials. Because the brain is incapable of this “memory”, there will be large variance in the EMG values of the clenches between trials. The most dependable clench force value for comparison is the maximum strength clench of each trial. The reason for this being that the brain is not required to “remember” the maximum force it can exert; the maximum force of the last clench for each trial is just the greatest amount of strength the muscles can exert and therefore has a more consistent nature than the intermediate clenches of medium

strengths. There is a general trend in the data that the percentage difference in the Integrated EMG mean (indicative of arm strength) between the two arms is much less for the last clench, which exerts the maximum force, than for the preceding clenches. The chart below shows supporting data for this general trend:

% left and right arm difference	
Chris, trial 1	
	mean
Cluster 1	52.24685
Cluster 2	61.00984
Cluster 3	10.56927
Cluster 4	19.38438
Chris, trial 2	
Cluster 1	47.48617
Cluster 2	36.2924
Cluster 3	-10.4454
Cluster 4	-11.04934



Therefore, in the remaining analysis, the only clench force which will be used for comparison purposes will be the fourth one of each cluster, which is the one of maximum force. Another reason why the data cannot be reproduced is due to the effect which fatigue will have on muscle strength (The effect of fatigue on muscle activity is discussed in the later analysis dealing with lesson 2). With repeated trials in close succession to each other, fatigue will build up in the muscle causing a decrease in its strength. As a result, the muscle is incapable of reproducing the various levels of clench forces exactly as before. Due to this second factor of non-reproducibility between trials, it was futile to perform several more trials in order to increase the precision of the data.

Although quantitative, statistical significance cannot be performed, some qualitative interpretations and moderate numerical analysis can be used to show differences in the strengths of the forearms for each patient. In subject 1 (Chris), who is ambi-dexterous, the percentage difference in the Ch 40 Integrated EMG mean (indicative of overall arm strength) between his left and right arm, is 19.38% for Trial 1 and 11.05% for Trial 2. For subject 2, David, who is right-handed, the percentage mean difference of the two arms are 33.01%, 22.36%, 32.64%, and 23.32% for Trials 1-4. These percentages show that there is much more difference in the two arm-strengths in a person who is predominantly right- or left- handed, versus someone who is ambi-dexterous.

As can be seen from Fig. 1 above, although Subject 1 and Subject 4's non-dominant arm has larger slope of integrated EMG vs. force, indicating that the motor recruitment of the non-dominant arm is greater than that of the dominant arm, that of subject # 2 and 4 is exactly reversed. This must be partly accrued to the uncertainty associated with the plots of the subjects. For Subject 2, for linear regression of dominant arm plot, the R value was a mere 0.9599 (as opposed to the other arm's R regression value of 0.9839). For Subject 3, R values are 0.9654 and 0.9461 respectively. In contrast, the R values of Subject 1 and 4 plots range from 0.9870 to 0.9960. The motor recruitment of Subject 2 and 3 are thus less consistent than that of Subject 1 and 4.

To evaluate whether or not there is a significant difference in the motor recruitment between the dominant and the non-dominant arm, a paired t-test for two means was carried out for Subject 4 (Subject 4 was chosen because Subject 1 claims to be ambidextrous, despite a predominant use of one arm over another). The test shows that the t-stat of the two means is  $-1.75$ , compared with the t-critical of  $12.706$ . Since t-stat is much less than t-critical, the motor recruitment of the subject's non-dominant arm is not significantly different from that of the dominant arm. Similar results were obtained when comparing the maximum clench force developed between the two arms. T-stat is  $1.6379$ , much less than the critical number of  $12.706$ .

In the table of Integrated EMG vs. Force, there is a correlation between muscle recruitment and strength. Across subjects, it can be seen that, if the subject weight is taken as a rough estimate of a subject's muscular development, then there is a trend of higher motor recruitment with less muscular development (see Fig 1). The motor recruitment between the subject with the most muscular development (Subject 1) and that of the least (Subject 4) is significantly different, with a t-test stat value is  $-41.75$ , compared with t-critical  $12.706$ . Similarly, there is a significant difference between the maximum clench force of the subjects: maximum clench for Subject 1 is  $46.03984$  kg with variance value of  $9.3188$  and  $21.33495$  with variance of  $14.773$  in Subject 4. This amounts to a t-stat value of  $44.2158$ , much greater than the t-critical value of  $12.706$  and thus indicates a significant difference. From a strictly qualitative analysis, Subject 1 has the greatest strength, the most muscle mass and the most muscle tone, and at the same time he has the optimal muscle recruitment: for any given amount of force applied, he has the lowest motor recruitment. The results agrees with the idea that more developed muscle has higher motor unit numbers, i.e. more muscle fibers per nerve fiber. As a muscle is called to do strenuous work, if more muscle fibers are available per motor unit as in a stronger muscle, then less motor units must be activated to do the same amount of work than in a weaker muscle with less muscle fibers per motor unit. For a stronger muscle, this equates to less action potentials for a given force and lower EMG values.

Subjects 1 and 4 repeated both the incremental force test and the fatigue test. For the incremental force test, since there is feedback on the EMG indicating how much is being applied, it would seem that the test is reproducible and consistent data on muscle recruitment per unit of force can be obtained. However, this is not entirely true. A closer inspection of the data (Fig 1) reveals that for the two subjects who repeated this test, the second trials consistently reveal higher motor unit recruitment per unit force. This is probably because after the first trial, there is an element of fatigue in the muscles, thus more motor units have to be activated to reproduce the same amount of force. To determine whether the two trials were actually different, a paired t-test between two means was carried out, comparing the means of Subject 1 and 4's first trial results to that of their second trials. The results indicate that the t-stat was  $-5.03$ , which is actually larger (in magnitude) than the t-critical of  $3.18$ . This indicates that the first and second trials were significantly different and therefore the test was irreproducible.

Similarly, the fatigue test is irreproducible, not only because of earlier fatigue induced on the muscle, but also because of the inherent unpredictability of the test. First, the maximum clench force depends on many variables, including the fatigue from earlier trials and most importantly the muscle control of the test subject. Any distractions the subject may have had during testing will also affect the data. A clear example of unpredictable data trends can be found while examining Subject 1's data. The fatigue test done on this individual shows the steadily decreasing applied force over time, naturally. However, upon closer inspection we see that during the decrease in force, there are multiple values which are neither increasing nor decreasing, but rather are oscillating between values less than the max and greater than the 50% max value. This shows that the subject was struggling to maintain the force originally applied to the grip. This is an example of the factor of will power affecting the data. Another example of unpredictability can be found in Subject 4's data. Although during the second trial, the maximum clench strength was 21.95% higher than that of trial one, almost suggesting that the subject's muscles were not, in fact, fatigued, the time to fatigue decreased by 29.46 %.

**THIS IS A COMPLEX ARGUMENT AND YOU PRESENT IT WELL AND RAISE SOME GOOD POINTS. WELL DONE  
GRADE 40/40**