Skeletal Muscle

Identification

Student Name (or ID)

[redacted]

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Case study

You are working as a physiotherapist at the Royal Brisbane & Women's Hospital. One of your patients has recently recovered from an operation which left them bedridden for 2 months; they have suffered chronic muscle atrophy during this time. A vital aspect of your role in the patient's recovery is to improve their coordination and muscle strength, and explain how this can be achieved to the patient.

Hypothesis 1

Increasing the strength of stimulus applied to the sciatic nerve of *Bufo marinus* will increase the peak of the active force generated by its gastrocnemius muscle to a maximal force.

Prediction of results 1

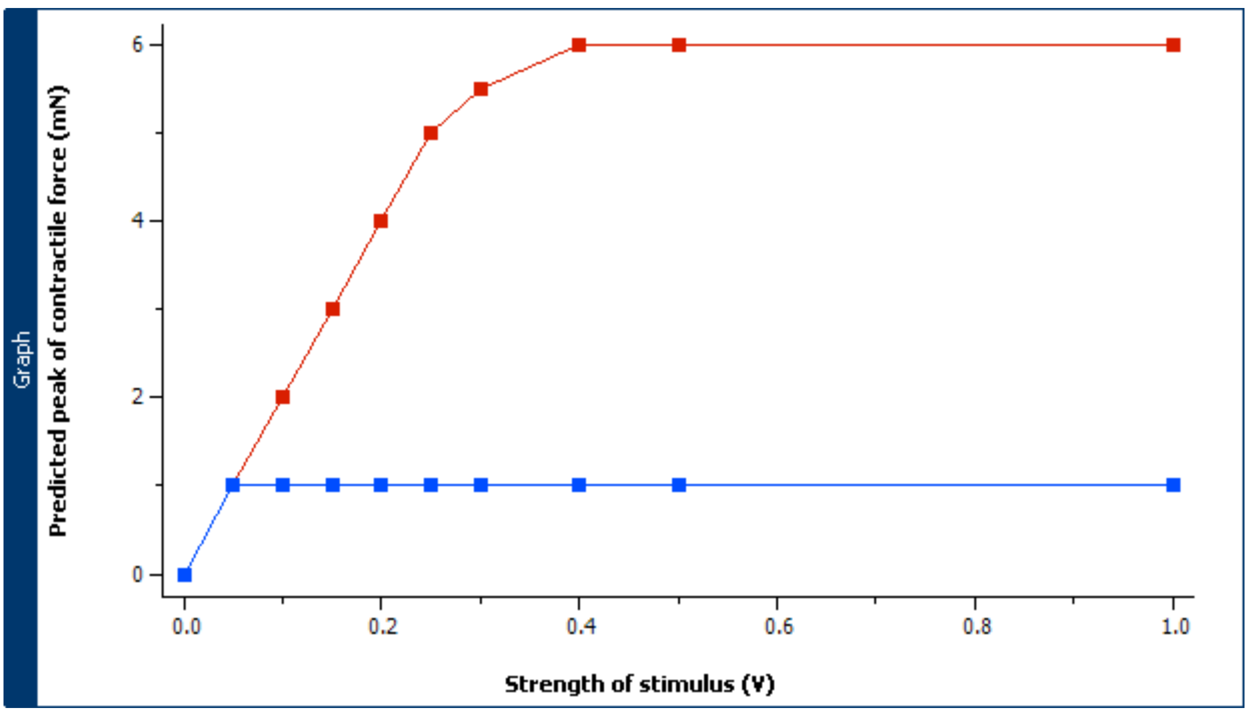

Figure 1: Predicted effects of stimulus strength applied to the sciatic nerve on the peak of the active force generated by the gastrocnemius muscle of *Bufo marinus*. Plots represent theoretical data if hypothesis is confirmed (red) and if the response is unaffected (blue).

Results 1

Table 2: Height of the peak of active contractile force generated by *Bufo marinus* gastrocnemius muscle (mN) measured from a passive force of 200mN				
Strength of Stimulus (V)	Replicate 1	Replicate 2	Replicate 3	Mean
0.00	0	0	0	0
0.05	12	11	12	11.66666666666667
0.10	574	363	419	452
0.15	602	354	520	492
0.20	1017	762	1029	936
0.25	1028	875	1071	991.333333333333
0.30	1023	945	1073	1013.66666666667
0.40	1094	998	1069	1053.66666666667
0.50	1082	1010	1066	1052.66666666667
1.00	1061	1036	1096	1064.33333333333

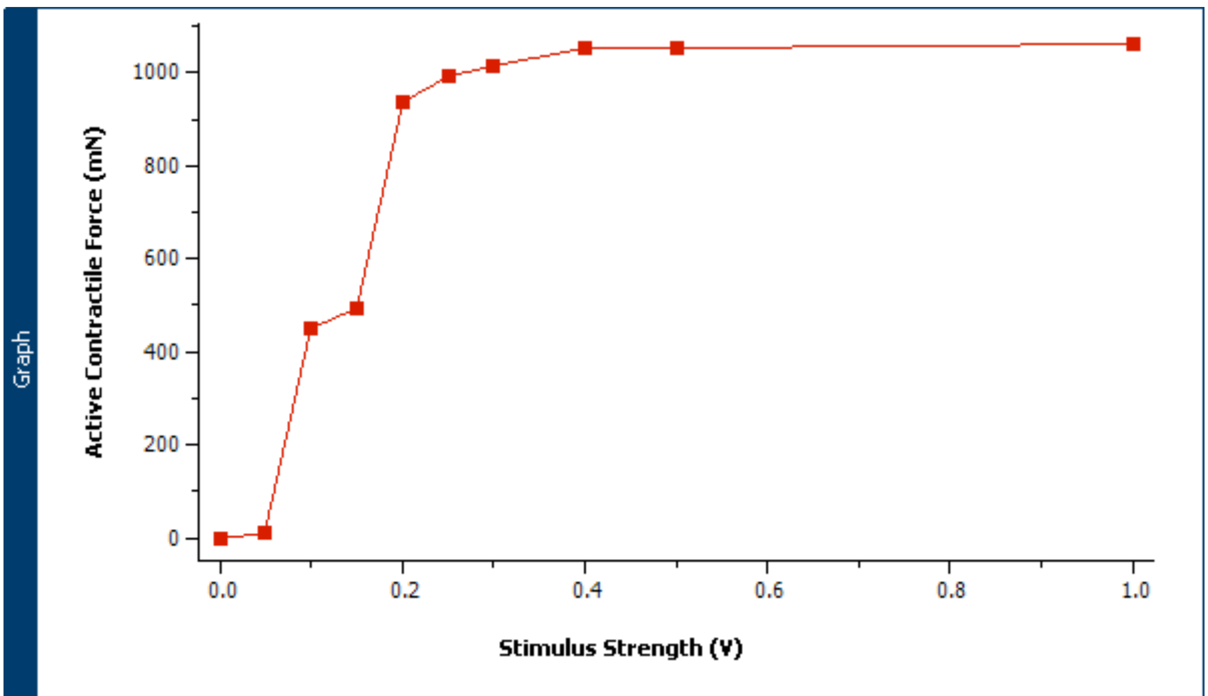

Figure 2.

Average of the three recordings of the height of active contractile force peak generated by the gastrocnemius muscle for increasing stimulus strengths applied to the sciatic nerve of *Bufo marinus* from a passive force of 200mN.

Comparative analysis

Table 3.		
Comparative analysis of the maximum peak of the contractile force generated by the gastrocnemius muscle of *Bufo marinus* and the minimum stimulus required on the sciatic nerve to produce such a force.		
Group	Maximum contractile force generated (mN)	Minimum stimulus required to generate maximum contraction (V)
Your own	1096	0.4
Alternate 1	1533	1
Alternate 2	959	0.5

Hypothesis 2

Decreasing the interval between each of the stimulus applied to the sciatic nerve of *Bufo marinus* will increase the peak of active contractile force generated by its gastrocnemius muscle.

Materials and methods 2

The power lab machine and the stimulating electrode were used to apply and record the strength and interval of each stimulus while force transducer was used to measure the amount of force generated by the gastrocnemius muscle of *Bufo marinus*. The force transducer was first calibrated using a weight of known mass so that it would give more meaningful units of force (mN). The nerve was then placed on the nerve bath where the stimulating and recording electrodes were connected and the muscle was tied to the force transducer. The stimulus used was 0.5V and the passive force was about 200mN. The force generated by the muscle with only the passive force acting on it (ie. without any stimulus) was recorded and this was the negative control. A stimulus was then applied to the sciatic nerve and the first peak was measured from 200mN, and this was the positive control. Ten different intervals, ranging from 0.5ms to 1000ms, were then tested with five successive stimuli. The final peak was then measured for each of the ten different intervals, from 200mN as well, and the values were recorded. Frog ringer solution was constantly poured on the nerve and muscle throughout the experiment to keep them from drying out and it was made sure that the passive force was adjusted to about 200mN before each of the stimuli.

Prediction of results 2

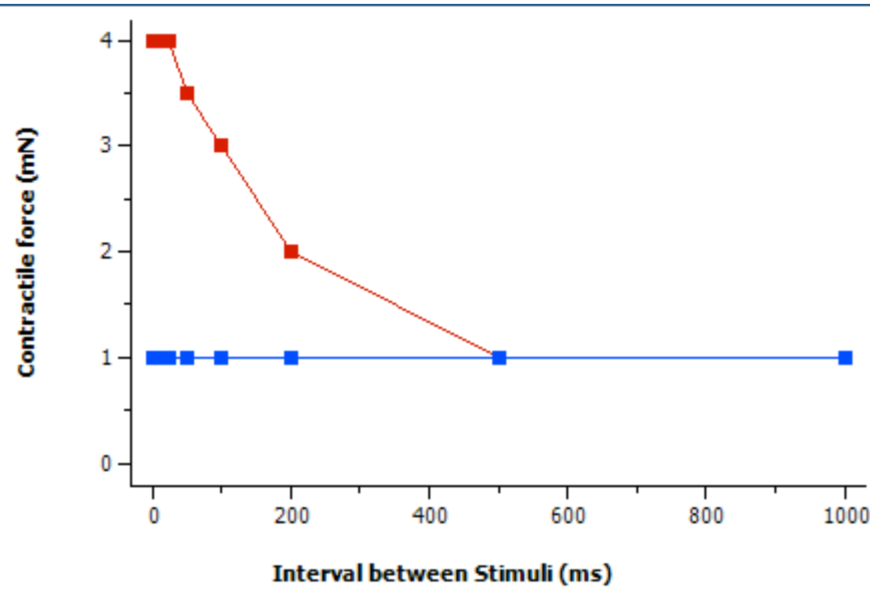

Figure 3.
The predicted effect of increasing the interval between each stimulus applied to the sciatic nerve of *Bufo marinus* on the active contractile force generated by its gastrocnemius muscle. Plots represent theoretical data if hypothesis is confirmed (red) and if the response is unaffected (blue).

Results 2

Write a paragraph of text in the box below, describing the important trends and relationships for all data presented from experiment 2:

The trend in figure 4 shows a continuous increase in the height of the peak of active contractile force as the interval between each stimulus increases from 5ms to 10ms where the maximum peak can be observed. After an interval of 10ms, further increase in the interval between each of the five stimuli result to a decrease in the peak of the active force. The relationship between the increase in the interval between stimulus from 5ms to 10 ms and the height of the peak of the active force as shown in figure 4 appears to be linear while from 10ms onwards, the relationship appears to be a curve with a negative power function.

Table 5.
The final peak of active contractile force generated by the gastrocnemius muscle of *Bufo marinus* after five successive stimuli of half a volt on the sciatic nerve with various interval in between each stimulus from a passive force of 200mN.

Independent Variable (units)	Replicate 1	Replicate 2	Replicate 3	Mean
0.5	669	769	811	749.66666666667
1	857	877	844	859.33333333333
5	1295	1492	1468	1418.3333333333
10	1389	1645	1634	1556
25	1280	1618	1674	1524
50	1080	1362	1424	1288.6666666667
100	758	916	968	880.66666666667
200	657	581	524	587.33333333333
500	502	483	440	475
1000	462	470	418	450

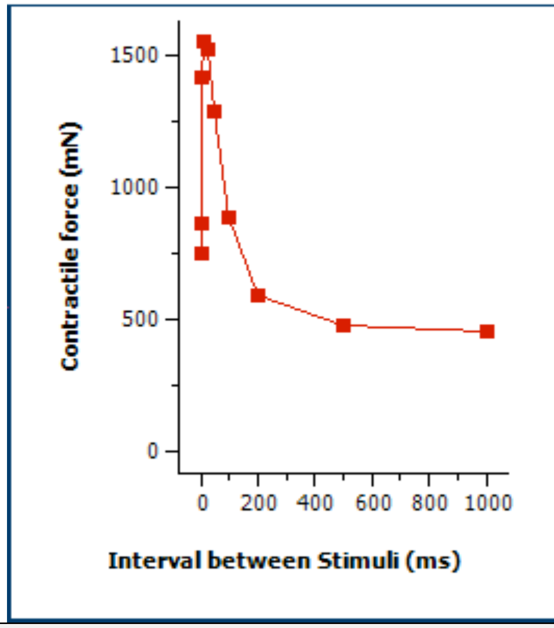

Figure 4.
Average of the three recordings of the height of the final active contractile force peak generated by the gastrocnemius muscle after five successive stimuli of 0.5V for increasing interval between each stimulus applied to the sciatic nerve of *Bufo marinus* measured from a passive force of 200mN.

Discussion

Remember to treat these questions like a short answer question in the final exam: be specific, clear, and concise.

1. Briefly describe (in complete sentences) whether the results of your first experiment confirm or disconfirm your hypothesis, and any errors in your data.

> The results obtained in the first experiment support the given hypothesis that increasing the strength of stimulus applied to the sciatic nerve of *Bufo marinus* will increase the peak of the active force generated by its gastrocnemius muscle until it reaches a certain point where further increase in the stimulus will no longer increase the peak and thus, it will remain constant. As figure 2 shows, the average peak of the contractile force continuously increased until about 0.4V where the peak reached its maximum value of approximately 1055V. Both figure 1 and figure 2 show the same trend, suggesting that the result of the first experiment indeed support what was hypothesised- that as the stimulus strength applied to the sciatic nerve increases, the peak of the active force generated by the gastrocnemius muscle also increases until it reaches the maximum stimulus voltage.
>
> A possible source of error that may have affected the results obtained was the variation in the strength of the passive force as passive force affects how strong the muscle contracts (Brennett, 2012). The passive force used in each stimulus was not exactly 200mN but a value ranging from 180mN to 210mN. This may have affected the precision of the results minimally but not the overall trend.

2. Why do you think the peak contractile force changes with different stimulus strength?

> The strength of a stimulus affects how many muscle fibres are activated when it is stimulated (Campbell, 2009). What determine how strong a muscle will contract are the size and total number of muscle fibres. By increasing the strength of the stimulus, therefore, more motor units are stimulated and thus, the higher the peak contractile force becomes as it is the measure of how strong the force generated by the contraction is. On the other hand, there would be less number of motor units activated when the stimulus applied is weaker.

3. What are the biological reasons for the differences between muscles in your comparative analysis?

One biological reason that could account for the differences between the muscles in the comparative analysis in table 3 was the variation in their mass. It can be expected that the muscle with the largest mass will generate the greatest force as it should contain more muscle fibres, and since the muscles obviously varied in mass, then there should also be a variation in the active force generated. Other possible reasons for the differences were the age of the muscle as well as the amount of damage they have. It is reasonable to assume that aged and damaged muscles would not function as well as undamaged muscles (Shavlakadze, 2003). If the muscles used were very far apart concerning their age-gap, then this would really account for the variation shown in the comparative analysis.

4. Briefly describe (in complete sentences) whether the results of your second experiment confirm or disconfirm your hypothesis, and any errors in your data.

The results obtained in the second experiment support the given hypothesis that increasing the interval between each of the stimuli applied to the sciatic nerve of *Bufo marinus* will decrease the peak of active contractile force generated by its gastrocnemius muscle, but as the figure 4 show, this is only the case from an interval of 10ms onwards. As figure 4 shows, the average peak of the contractile force continuously increased from an interval of 0.5ms in between each of the five stimuli to 10ms. The maximum peak can be seen when the interval is 10ms and as the interval increases from this point, a decrease in the peak can be observed. Both figure 3 and figure 4 show mostly similar trend, suggesting that the result of the second experiment indeed support what was hypothesised- that as the interval between stimuli increases, the peak of the active contractile force decreases, however, this is only the case from an interval of 10ms onwards as intervals below this value has the opposite effect on the peaks.

5. What biological processes do you think have caused the trends your results illustrate?

As a response to a stimulus, muscle fibres produce a twitch then they relax. When the interval between two stimuli is decreased to an extent where the second stimulus comes before the muscle fully relax from responding to the previous stimulus, there would be a stimulus on top of the first, resulting to a development of a greater total force and thus, a higher peak of active force generated by the muscle (Campbell, 2009). When the interval between stimuli is small enough, there would be a point where the contractions from five successive stimuli fuse into one smooth and powerful contraction called tetanus (Campbell, 2009). The height of the peak of active force generated when the intervals were 0.5ms and 1ms were smaller than the peak when the interval was 10ms despite the fact that they were shorter intervals because there was not enough time for the responses to fully reach their peaks before the next stimulus came along. Thus, the final peaks for these responses were not very high.

6. In the case study you are working on muscle atrophy, how do you think increasing muscle mass would affect the contractile force generated for a given stimulus?

It is reasonable to expect that there would be a greater number actin and myosin to produce a contraction with greater mass. Thus, increasing muscle mass would increase the number of motor units that can be activated and therefore, the contractile force generated for a given stimulus is also increased (Galves, 2000). Muscle atrophy, however, would decrease the strength of the contractile force generated as this is a condition where the muscle volume is decreased. As the muscle volume is decreased, the number of motor units that can be activated also decreases and thus, it can be expected that the contractile force that is generated would be weaker.

7. The patient you are treating does not have a strong science background; explain to them (using complete sentences) how stimulation of skeletal muscle can result in different strength contractions using language which they can understand.

There are two main factors that contribute to the strength of contraction generated by a skeletal muscle(Campbell, 2009). Firstly, strength of muscle contraction can be influenced by the intensity of stimulation. How strong a stimulus is determines how many muscle fibres are activated to generate a contraction. The stronger the stimulation, the more muscle fibres are activated and thus, the stronger the contractile force becomes. On the other hand, the number of muscle fibres stimulated when the stimulus applied is weaker will be less and therefore, the contraction will also be weaker. Secondly, the length of the interval in between stimuli also affects the strength of contraction. When the interval between two stimuli is short enough, there would be a twitch on top of a twitch that would result to a greater contractile force. The interval can be decreased to an extent where the contractions from successive stimuli fuse into a tetanus which is a smooth powerful contraction.

References

List any references you have used in the panel below:

Brennett, M. (2012). Lecture 3.1: Skeletal Muscle- chemical energy to mechanical work. BIOL1040 Module 3 Lectures, The University of Queensland, Australia.

Campbell, N.A., Reece, J.B., Meyers, N., Urry, L., Cain, M.L., Wasserman, S.A., Minorsky, P.V., Jackson, R.B. and Cooke, B.N. (2009). Biology, 9th Ed: 1301-1313.

Galves, J.M., Alonso, J.P., Sangrador, L..A. and Navarro, G. (2000). Effect of muscle mass and intensity of isometric contraction on heart rate. Journal of Applied Physiology **88**(2): 487-492.

Shavlakadze, T. and Grounds, M.D. (2003). Therapeutic interventions for age-related muscle wasting: importance of innervation and exercise for preventing sarcopenia. Modulating aging and longevity **5**(9): 139-166.