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National Taiwan University

The effect of backpack loading ontrunk posture and upper-trunk musclesin young adults while walking

The effect of backpack loading on trunk posture and upper-trunk muscles in young adults while walking

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Abstract –
Background and objective:

Young adults such as university or graduate students, are common users of backpacks.While Improper backpack use, such as excessive loading weight and long duration of backpack carriage, imposed postural change with potential to raise the risk of various negative consequences of abnormal body posture. such as forward head, rounded shoulders, and forward trunk lean. Due to the impotantance of the issues, We aimed to assess the impact of backpack carriage on postural angles and upper trunk muscles fatigue while walking. Moreover, the secondary purpose was to investigate the relationship between muscle fatigue measurement and subjective discomfort feelings.

Methods:

This study recruited 3 male students who were were backpack users. The postural change and severity of muscles fatigue of the participants were recorded while they walked on a treadmill. Experimental meausurements were 3D-motion capture system , surface electromyography and Visual analog scale. Our major measurement of posture angles was Cranio-vertebral Angle (CVA) and Sagittal Shoulder Angle (SSA). Besides, we also analysed the frequncy index as objective measurement of muscles fatigue.

Results:

There was a difference in cranio-vertebral angle and sagittal shoulder angle after wearing 10% and 20% body weight backpack in 30 and 60 minutes respectively. CVA and SSA were becoming smaller and it affected the rectus abdominus muscle to contract more. For the other muscles such as lower and upper trapezius, erector spinae, midcervical paraspinals muscle, and sternocleidomastoid there was no significant difference in fatigue index.

Conclusions:

Walking on the treadmill for a long duration might have several consequences.
We found that forward head posture appeared and trends for muscles of fatigue in neck, shoulder and back muscles. We need to consider the loading of backpack and the duration when we use backpack.
Keywords – backpack loading , fatigue index, posture

1. INTRODUCTION

Using backpack is a common task in our life. Different people carry backpacks for different purposes(Al-Khabbaz, Shimada, & Hasegawa, 2008). Young adults such as university or graduate students, are common users of backpacks, typically carrying physically demanding loads during their daily routines to and from school(Abaraogu et al., 2017). Improper backpack use, such as excessive loading weight and long duration of backpack carriage, imposed postural change with potential to raise the risk of various negative consequences of abnormal body posture.

Posture is the amalgamation of the position of multiple joints, bones, and muscles along the longitudinal axis of the body. A neutral posture aligns these components in equilibrium.(Dahl, Wang, Popp, & Dickin, 2016). It is well documented that heavy school backpacks that severely impact posture cause adverse effects(Rai, Agarwal, Bharti, & Ambedakar, 2013). For instance, Singh and Koh (Singh & Koh, 2009) discovered that too much load on the spine changes both static and dynamic posture as the body tries to overcome the posterior shift in the center of mass(COM). However, continuous poor postural compensations can lead to musculoskeletal imbalances such as forward head, rounded shoulders, and forward trunk lean(Kim, Yi, Kwon, Cho, & Yoo, 2008). As the posture deteriorates, it could cause changes in muscle activity and muscle fatigue at first, then subsequently lead to body soreness. Eventually, posterior loads carried by students have also been linked to various types of body pain disorders including neck, shoulder, upper back and lower back pain(Rai et al., 2013).

Based on previous studies, there were some factors may induce poor posture of backpack carriage, such as excessive weight and duration time of backpack loading. Besides, it is still uncertain whether the timing of muscles fatigue between subjective feelings and changes of muscle activity measured by surface electromyography (sEMG) are distinguished. As for students who go to school carrying their backpack, it's crucial to consider the proper weight and duration time of backpack carriage to prevent abnormal posture and unnecessary muscle fatigue and body pain. The EMG data will be used for calculating median frequency and processed further to determine the fatigue index. It is preferable to use the median frequency as the fatigue index calculated from the frequency spectrum of the EMG signal.

Hence, the primary purpose of this study was to comprehensively assess the impact of backpack carriage on postural angles and upper trunk muscles fatigue while walking. Moreover, the secondary purpose was to investigate the relationship between muscle fatigue measurement and subjective discomfort feelings. We hypothesized that more weight of the backpacks carried, the sooner the postural angles changes and muscle fatigue appears. Secondly, we assumed timing differentiation of muscles fatigue between objective measurement by EMG and subjective feelings become obvious as the weight of backpacks added.

2. METHODS

Participants

This study recruited 3 male graduate students of National Taiwan University (mean age: 22.7 ± 0.6 , mean height: 170.2 ± 3.3 , mean body weight (BW): 66.0 ± 7.9). All participants were backpack users in their daily livings. Furthermore, they were all right-handed and healthy with no reported musculoskeletal problems or body pain which may affect the experimental procedure in the 3-month period prior to the study. They both were informed of the details of the procedure. Adults older than 30 years were not accepted for the study in order to reduce the potential confounding effects of age on the postural assessments. Also, individuals had recent injury, postural deformities, chronic muscles pains on neck, shoulder and back, history of spine surgery were excluded in our study.

Experimental design

The backpack-carrying postures of the participants were recorded while they walked on a treadmill at self-paced speed (3.0 to 4.0 m/s). We took previous studies(Abaraogu et al., 2017; Al-Khabbaz et al., 2008; Kim et al., 2008) as references to decide the weight of backpacks in our study, that was, 10%BW and 20%BW. Each participant would carry these loadings in two conditions respectively. In addition to backpack weight, attention has been given to the height of the backpack's center of gravity (COG). The position of the backpack is crucial for determining the proper load-carriage method(Chen & Mu, 2018). We decided the location of the COG of the backpack was standardized at the T12 spinal level. As to measure the muscle fatigue of backpack-carriage, the experimental time was corresponded to the weight of backpacks (carrying 10%BW for 60 minutes and 20%BW for 30 minutes). Moreover, we conducted the sequence of two conditions between different participants as randomization. All conditions were followed by at least 30mins rest to avoid accumulative fatigue.

Postural analysis

In our study, we used 3D-motion capture system (Vicon 8-cameras, T-40S, Oxford Metrics Group, UK) with reflective markers to assess posture changes. These markers were attached to each participant's anatomical landmarks on bilateral side (e.g., the external canthus of the eye, targus of the ear, acromion process, the spinous process of C7) to serve as referable points for the measurements(Abaraogu et al., 2017; Chen & Mu, 2018). Our major measurement of posture angles was Cranio-vertebral Angle (CVA) and Sagittal Shoulder Angle (SSA). CVA was measured by measuring the angle formed at the intersection of the horizontal line through the spinous process of C7, and the line drawn from the targus of the ear to the spinous process of C7(see angle A in Figure 1). This was believed to provide an estimation of the neck on upper trunk positioning. A small angle
indicated a more forward head posture(Chansirinukor, Wilson, Grimmer, & Dansie, 2001). Besides, SSA was also measured by the angle formed at the intersection of the horizontal
line through the spinous process of C7 and a straight line drawn from acromion process to the spinous process of C7(see angle B in Figure 1). A smaller angle of SSA indicated the shoulder is further forward in relation to C7, in other words, a more rounded shoulder)(Abaraogu et al., 2017; Raine & Twomey, 1994).

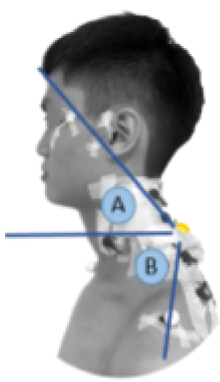

Figure SEQ Figure * ARABIC 1(A). Cranio-vertebral angle (B) Sagittal shoulder angle

Subjective and objective measurements of muscle fatigue

Surface electromyography (EMG) was utilized to study changes in neck and trunk muscle activities. Before attaching surface electrodes, electrode sites were cleaned with alcohol. Bilateral EMG of neck muscles were placed on sternocleidomastoid, midcervical paraspinals. And other EMG on muscles of bilateral upper trapezius, lower trapezius, erector spinae, and rectus abdominis were used to measure muscle activities of upper back, lower back, and abdominals(Kim et al., 2008). Data was sampled at 2160 Hz and amplified by an twelve-channel digital EMG system. To normalize EMG data, maximum voluntary contraction (MVC) was performed for all examined muscles(Dankaerts, O'Sullivan, Burnett, Straker, & Danneels, 2004). MVC records were taken before every conditions started. Each MVC trial lasted for 5 seconds and was followed by 2 minutes rest to avoid muscle fatigue. All vocal commands and were done by a recorder.

Visual analog scale (VAS) was used to assess the participant's subjective feelings of muscles fatigue or soreness in our study. VAS is widely used in clinical medicine to evaluate the severity of subjective symptoms(Wu, Chen, & Luo, 2014). The VAS reduces the reliance on written language(Hendey, Donner, & Fuller, 2005). Subjects only need to make a mark on a 10-cm horizontal line; the left end of the line is 0 cm, which indicates a lack of symptoms, and the right end is 10 cm which indicates that the symptoms are serious. A symptom intensity from 0 to 4 cm represents almost no symptoms; an intensity from 4.1 cm to 4.4 cm represents a mild level of symptoms; an intensity from 4.5 to 7.4 cm represents a moderate level of symptoms; and an intensity from 7.5 to 10.0 cm represents a severe level of symptoms.(Hendey et al., 2005; Jensen, Chen, & Brugger, 2003).

Procedures

All participants attended a single laboratory visit to do two experiments, wearing backpack weighted 10% and 20% of the subject body weight in 60 minutes and 30 minutes, respectively. Participants were recommended to wear sport shoes or comfortable shoes to avoid foot pain and to minimalize the impact force on foot. Before EMG attachment, the skin surface was wiped with rubbing alcohol to facilitate better attachment with reduced skin-electrode impedance. MVC tests were performed for every surface EMG attached on the participant, this later will be used for calculating index fatigue. There were three main markers that were used for calculating the cranio-vertebral angle and sagittal shoulder angle, which were located at targus of the ear, spinous process of C7 and shoulder acromion process. The backpack's COM (center of mass) were positioned at T12 spinal level and. Before starting the experiment, participants were asked to walk on the treadmill for two to three minutes to make the participants familiarized walking on it, then adjust the treadmill speed to their comfortable walking speed. The EMG data and movement data were captured every five minutes using VICON software. The captured data length was during the last thirty seconds of every five minutes and continued by asking the participants the VAS (Visual Analog Scale) for pain severity measurement. Experiment started with walking using 10% body weight backpack for 60 minutes and a minimum 30 minutes' break to prevent muscle fatigue then resume with 20% body weight backpack for 30 minutes. The whole process, attaching markers and EMG, experiment and rest took about four hours.

3. RESULTS

Cranio-vertebral angle(CVA)

Figure 2 showed the cranio-vertebral angle (CVA) with 10% and 20% of body weight respectively. The cranio-vertebral angles decreased in both 10% and 20% of body weight with different degrees. And it was more significantly decreased when carrying 10% of body weight than 20% of body weight.

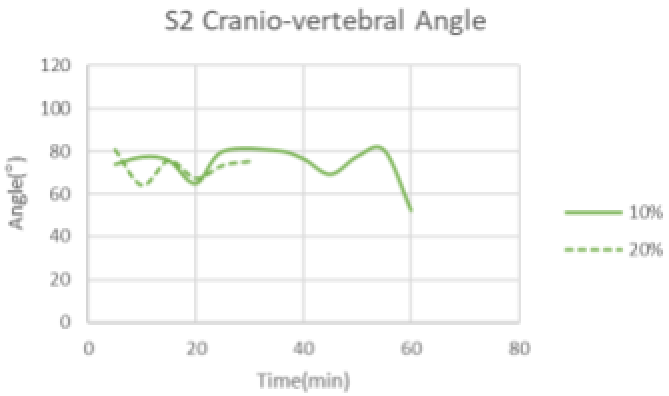

Figure 2. Subject 2 Cranio-vertebral Angle

Sagittal Shoulder Angle (SSA)

Figure3 showed the sagittal shoulder angle (SSA) with 10% and 20% of body weight respectively. The sagittal shoulder angle slightly decreased in both 10% and 20% of body weight.

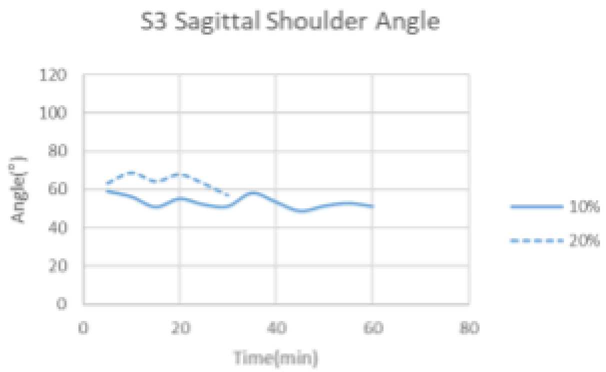

Figure 3. Subject 3 Sagittal Shoulder Angle

Median Frequency

As shown in Figure4, there was a decrease of median frequency in 10% body weight backpack wearing, starting with 76Hz and 62Hz at 60 minutes, while in 20% body weight, there is no significant difference between start and 30 minutes' mark.

Figure 4. Median Frequency of Lower Trapezius

Figure 5. Median Frequency of Upper Trapezius

The same result obtained froam upper trapezius muscle (Figure 5), in 10% and 20% body weight there is a slight reduction in median frequency. However there is a significant difference in rectus abdominis muscle (Figure 6), the median frequency started at around 50Hz and ended with 90Hz which means the between neck and shoulder angle affects the usage of abdomen muscle.

Fatigue Index

Figure 6. Median Frequency of Rectus Abdominis

Figure 6. showed fatigue index at MPS (midcervical paraspinals) muscle, rectus abdominis, upper trapezius and erector spinae are remained stable. The sternocleidmastoid (SCM) muscle trend is sharply inclined from time period of 10 minutes to 20 minutes when walking with 10% body weight backpack. From the graph it is also shown that Lower trapezius muscle also has an alteration in 60 minutes, the fatigue index are higher than the time experiment started..

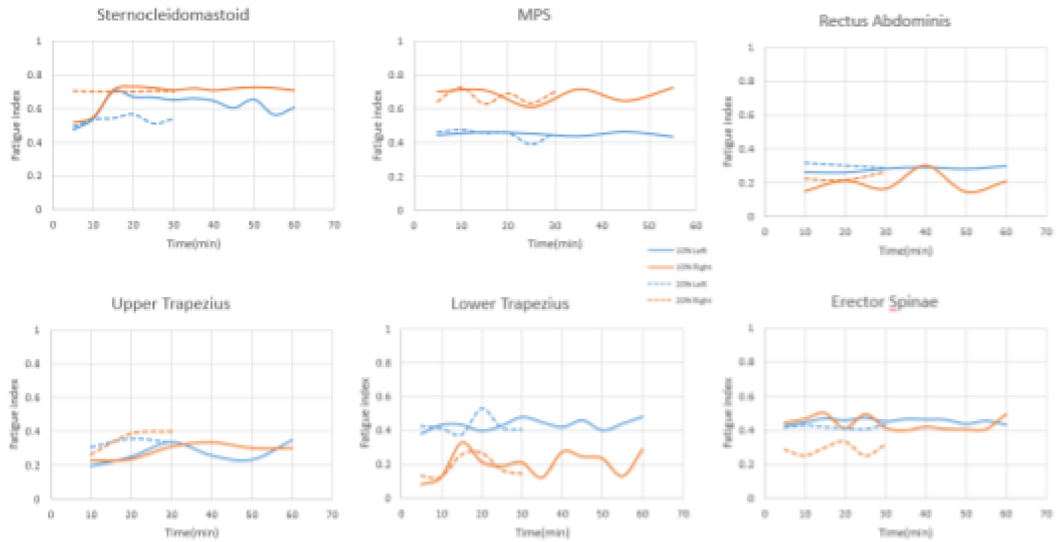

Figure SEQ Figure * ARABIC 6. Fatigue Index of Different Muscles

VAS (Visual Analog Scale) for pain severity measurement

The results of the VAS indicated that the subjective feelings of all participants rose to moderate level (4.5-7.5) after walking for about 20-25 minutes. When carrying 20% bodyweight, the VAS increased rapidly, regardless of which participant. Moreover, the first participant even reached to a severe level in less than 10 minutes. The second participant was the only one that did not reach a moderate level during a load of 10% bodyweight.

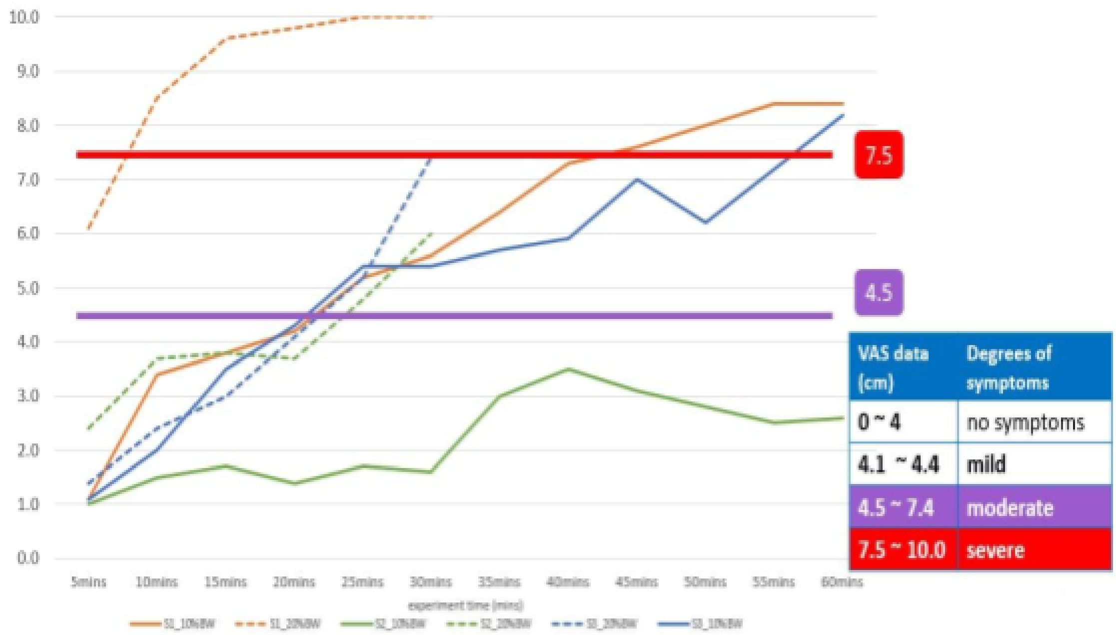

Figure 7. VAS data graph

4. DISCUSSION

Cranio-vertebral Angle(CVA) vs Sagittal Shoulder Angle(SSA)

One of the purpose of this study was to characterize the comparative cranio-vertebral angle and sagittal shoulder angle for the control condition when carrying 10% and 20% of body weight. Figure 1 and 2 shows that cranio-vertebral angle decreased more significantly than sagittal shoulder angle. Since the length of the experimental period was different between 10% and 20% of body weight, we can speculate that the forward head posture appeared earlier than rounded shoulder.

Median Frequency and Fatigue Index

It is preferable to use the median frequency as the fatigue index calculated from the frequency spectrum of the EMG signal (De Luca, 1997). There are two possibilities regarding to the result of median frequency in this experiment, first is since the participants are all male, healthy and young it is possible that all participants did not reach fatigue yet so the graphs shown are moderately stable. Second possibility is that the surface EMG did not attached properly since during the experiment, all participants were sweating which could affect the surface EMG and some noises will appear. However, there are a notable increase at rectus abdominis muscle's median frequency which are assumed to be the effect of cranio-vertebral angle and sagittal shoulder angle changes. From Figure 1 and Figure 2, it is shown that the upper body posture is leaning forward as the time goes by, and this phenomenon might result in rectus abdominis muscle contracted.

VAS

Based on the results of the VAS, we confirmed that all participants felt tired after walking on the treadmill for over 20 minutes. However, when we reviewed our process, we found that the design of VAS was not very comprehensive. We have only asked them how tired they felt orally. Maybe they were thinking the fatigue of the lower limb at the moment, or else other feelings. Thus, a more complete sheet must be designed before the experiment. For example, how exactly which part of the muscle is the participant feeling fatigue? These should be discussed seriously.

Limitations

There were several limitations in this experiment. Firstly, the participants have already known the procedures before conducting experiments, such as time duration and the equipment, causing them to walk unnaturally. Second, the VAS that we designed could not represent muscle fatigue comprehensively. We have only inquired how tired the participant was at the moment, but did not exactly figure out which part of the muscles participants were feeling fatigue. Generally speaking, we need to come up with a new method to obtain the results of VAS.

The selection of the backpack was another problem. We chose a soft backpack which was unable to maintain its shape, and it easily changed the position of the center of gravity while the participant carried it. Consequently, CVA and SSA might change either.

Last but not least, we have only found three participants in this experiment, meaning a really small sample size. If this project continues, we suggest to recruit more participants in order to get appropriate results.

5. CONCLUSIONS

Walking on the treadmill for a long duration might have several consequences. It affected forward head posture more obviously than the factor of backpack loading, as the participants done the experiment. On the other hand, Forward head posture was found to appear earlier than rounded shoulder, which was based on the results of CVA and SSA. As we conducted the survey for VAS, we can easily figure out that people tend to have subjective feelings of muscle fatigue as a moderate level after walking on the treadmill for 20-25 minutes. Moreover, the median frequency and fatigue index of rectus abdominis are going an opposite way in comparison with the other muscles. We consider as a compensation for the fatigue at neck and back muscles. Lastly, Among all the muscles, we observed the MDF trends of “upper and lower trapezius” declined. These results were similar to the feelings of the subjects.

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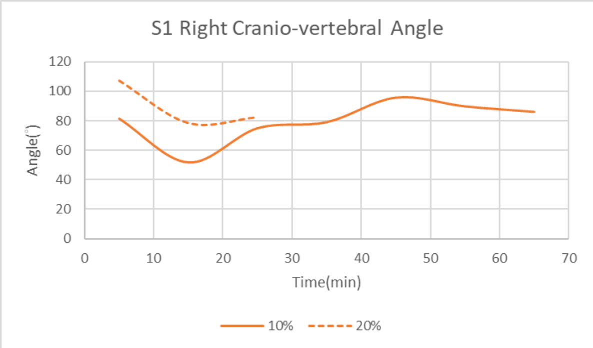
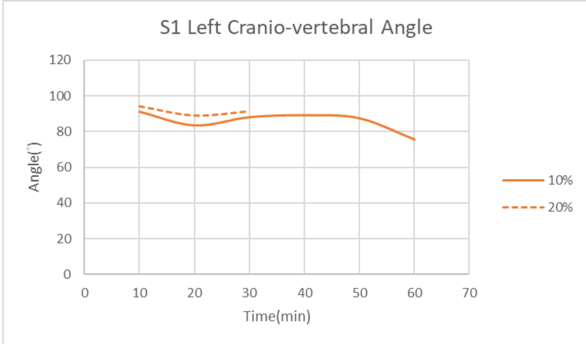
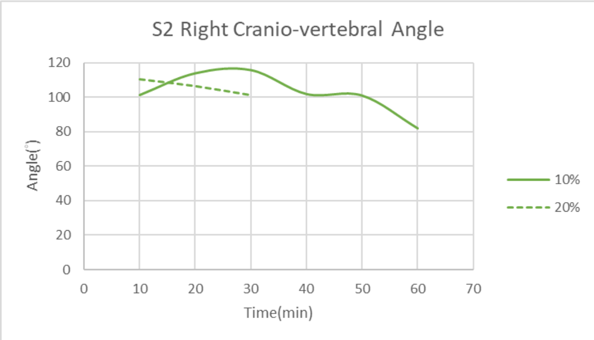
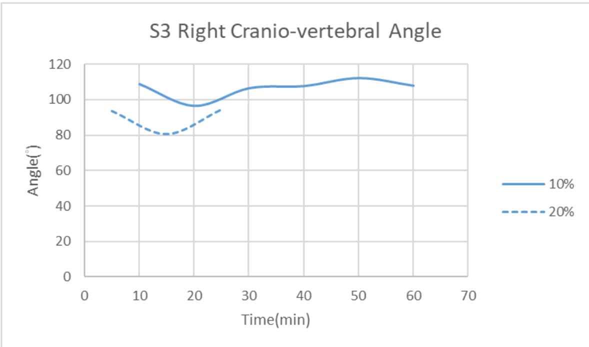
APPENDIX

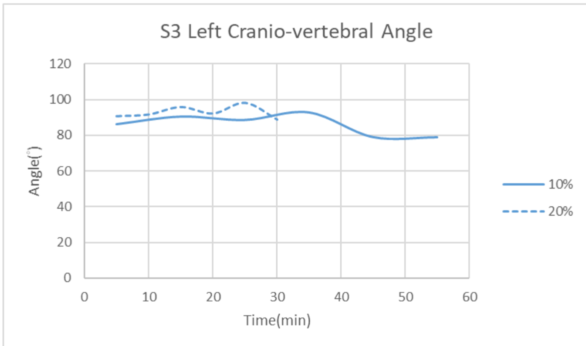
■ Cranio-vertebral Angle



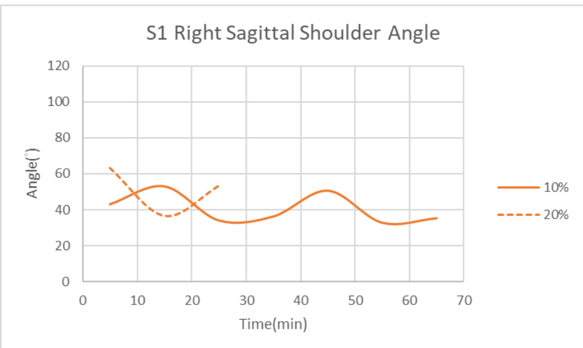


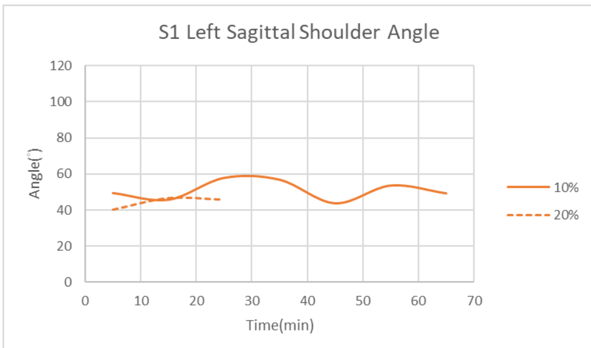


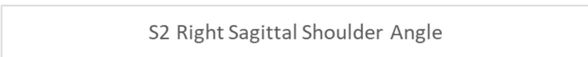


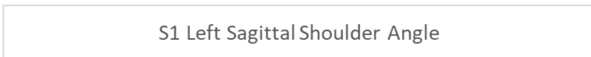


■ Sagittal Shoulder Angle

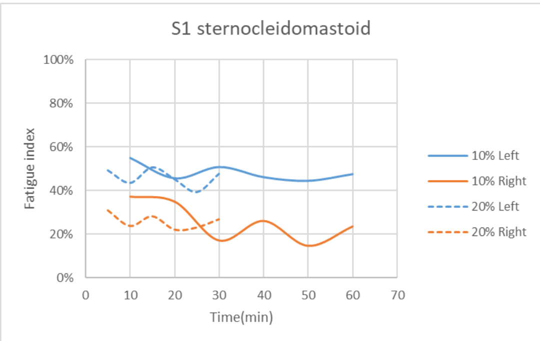


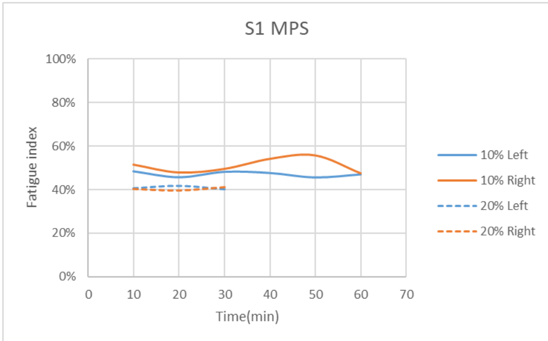


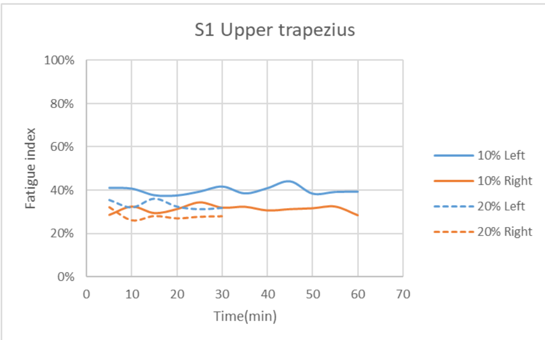


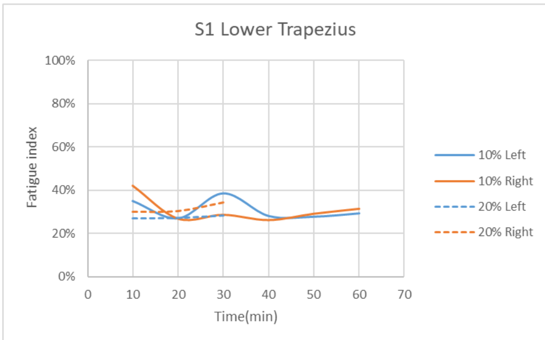


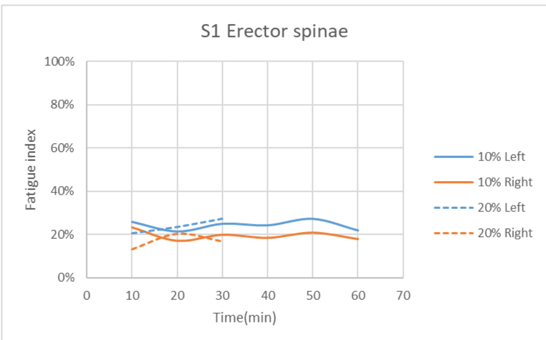
■ Fatigue index

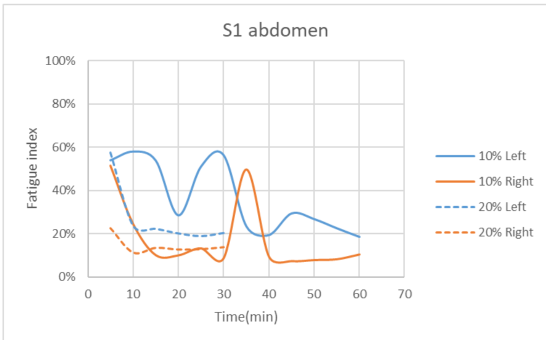


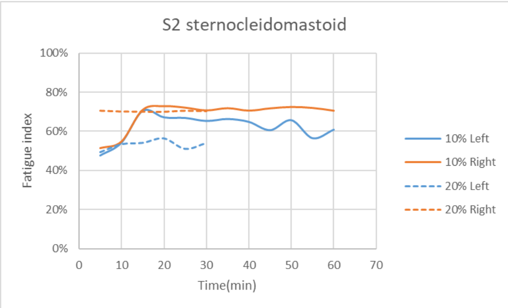


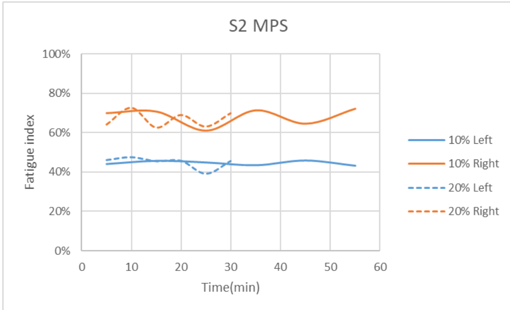


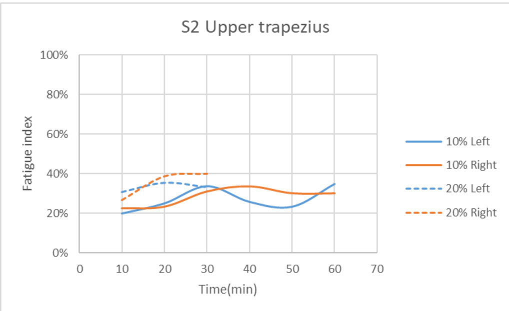


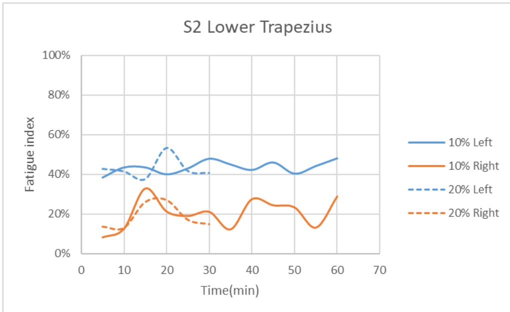





S2 sternocleidomastoid
Fatigue index
100%
80%
60%
40%
20%
0%
0 10 20 30 40 50 60 70
Time(min)
10% Left
10% Right
20% Left
20% Right


S2 MPS
Fatigue index
100%
80%
60%
40%
20%
0%
0 10 20 30 40 50 60
Time(min)
10% Left
10% Right
20% Left
20% Right


S2 Upper trapezius
Fatigue index
100%
80%
60%
40%
20%
0%
0 10 20 30 40 50 60 70
Time(min)
10% Left
10% Right
20% Left
20% Right


S2 Lower Trapezius
Fatigue index
100%
80%
60%
40%
20%
0%
0 10 20 30 40 50 60 70
Time(min)
10% Left
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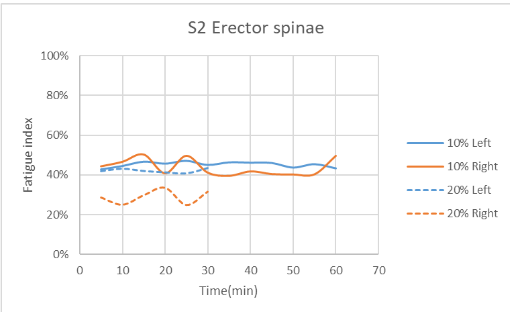
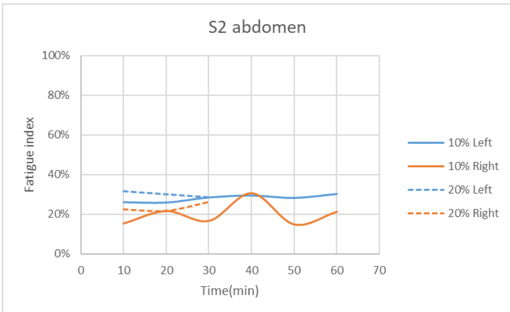
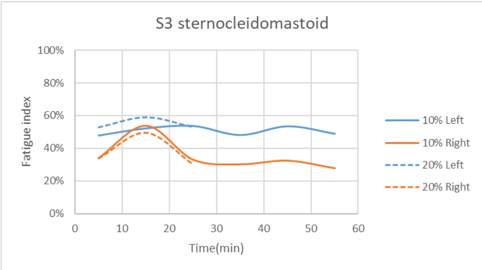
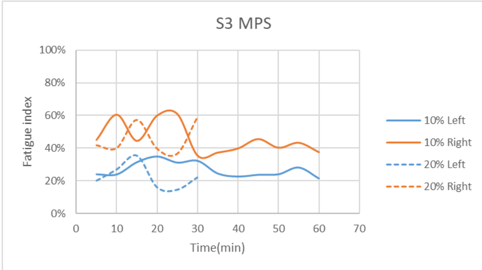
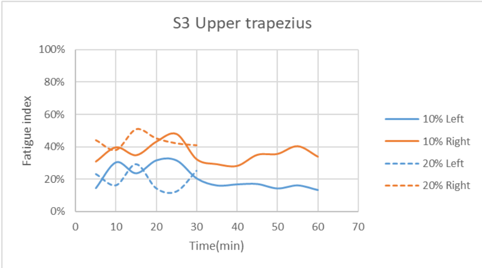
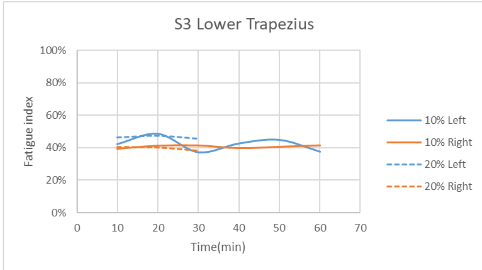

S2 Erector spinae
Fatigue index
100%
80%
60%
40%
20%
0%
0 10 20 30 40 50 60 70
Time(min)
10% Left
10% Right
20% Left
20% Right

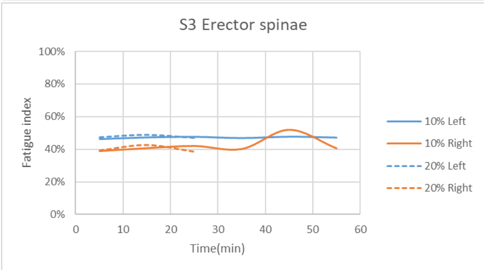

S2 abdomen
Fatigue index
100%
80%
60%
40%
20%
0%
0 10 20 30 40 50 60 70
Time(min)
10% Left
10% Right
20% Left
20% Right

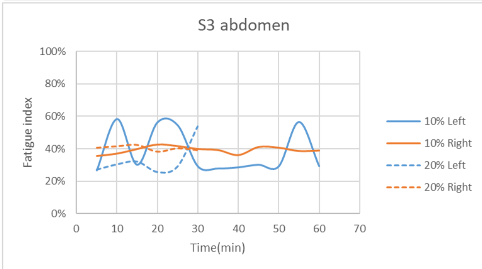




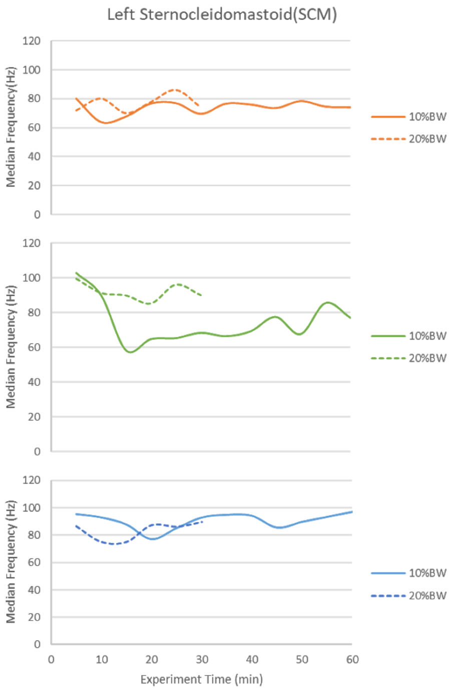


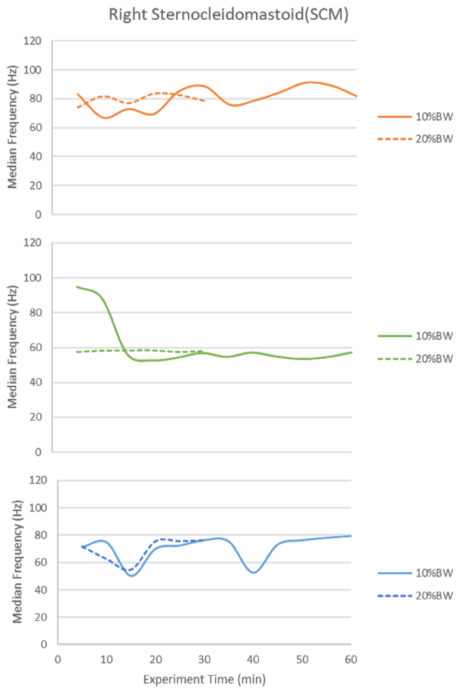


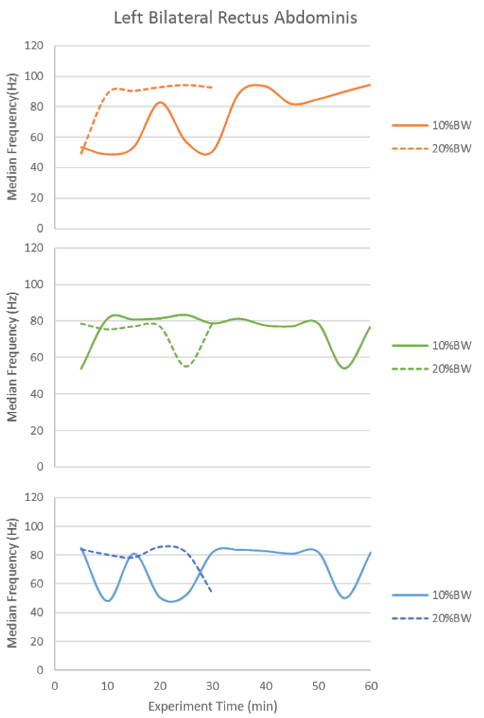


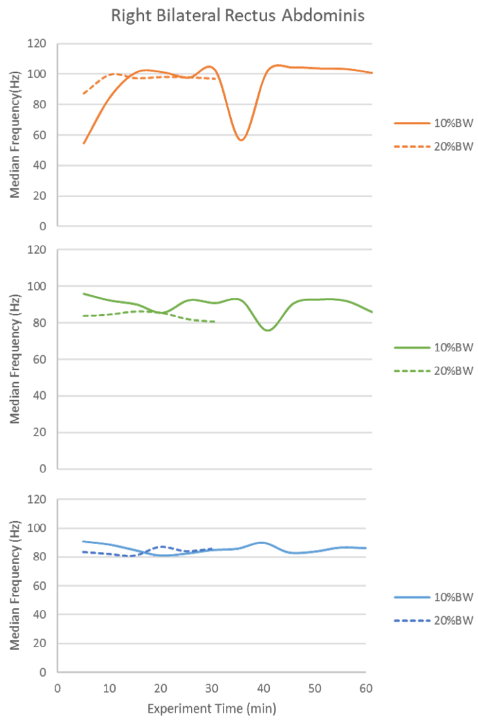


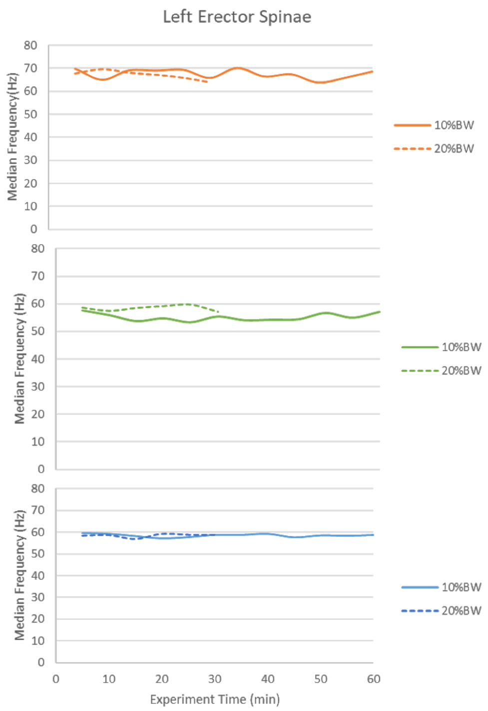
- Median Frequency

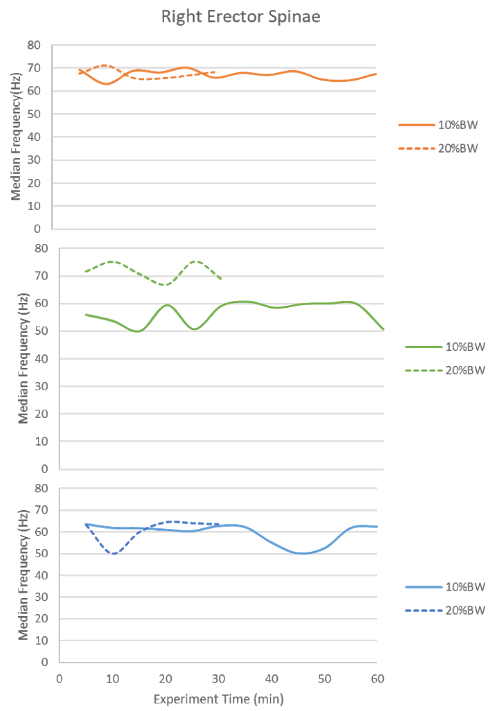


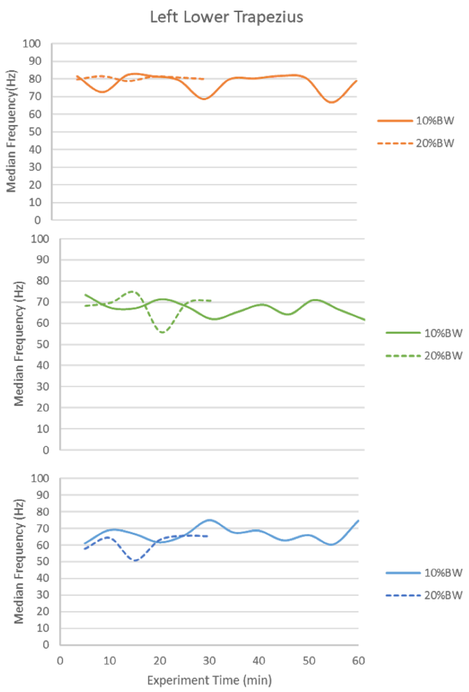


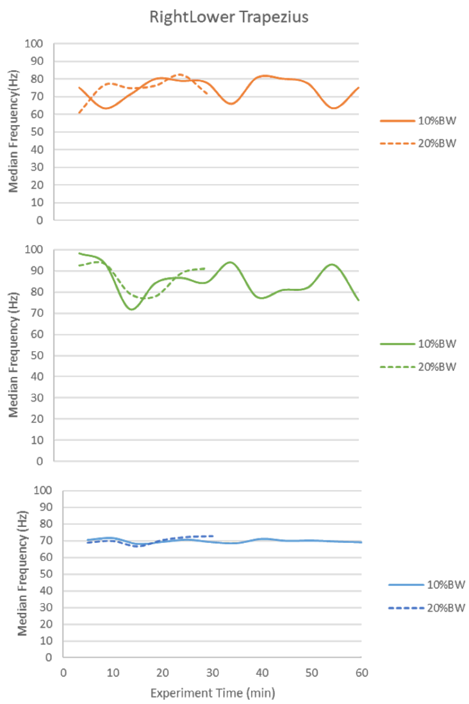

Left Bilateral Rectus Abdominis
Median Frequency(Hz)
Median Frequency (Hz)
Experiment Time (min)
10%BW
20%BW

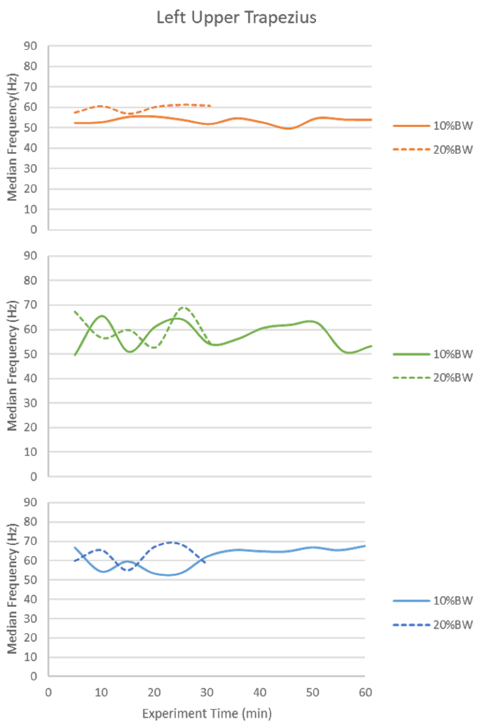

Right Bilateral Rectus Abdominis
Median Frequency(Hz)
Median Frequency (Hz)
Experiment Time (min)
10%BW
20%BW

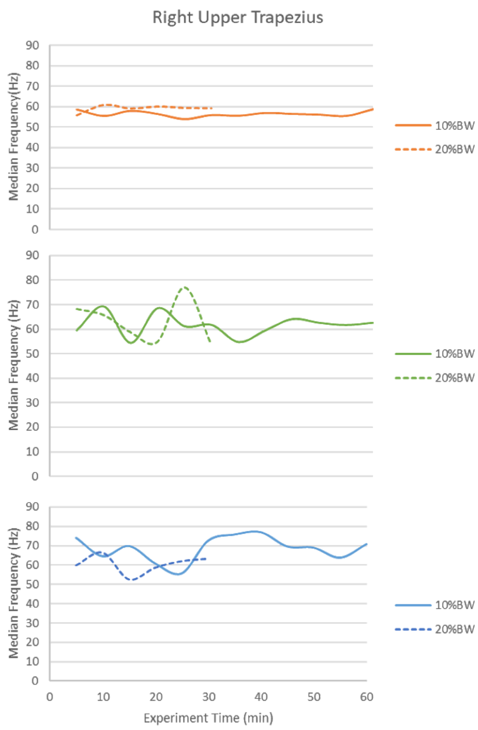

Left Erector Spinae
Median Frequency(Hz)
Median Frequency (Hz)
Experiment Time (min)
10%BW
20%BW

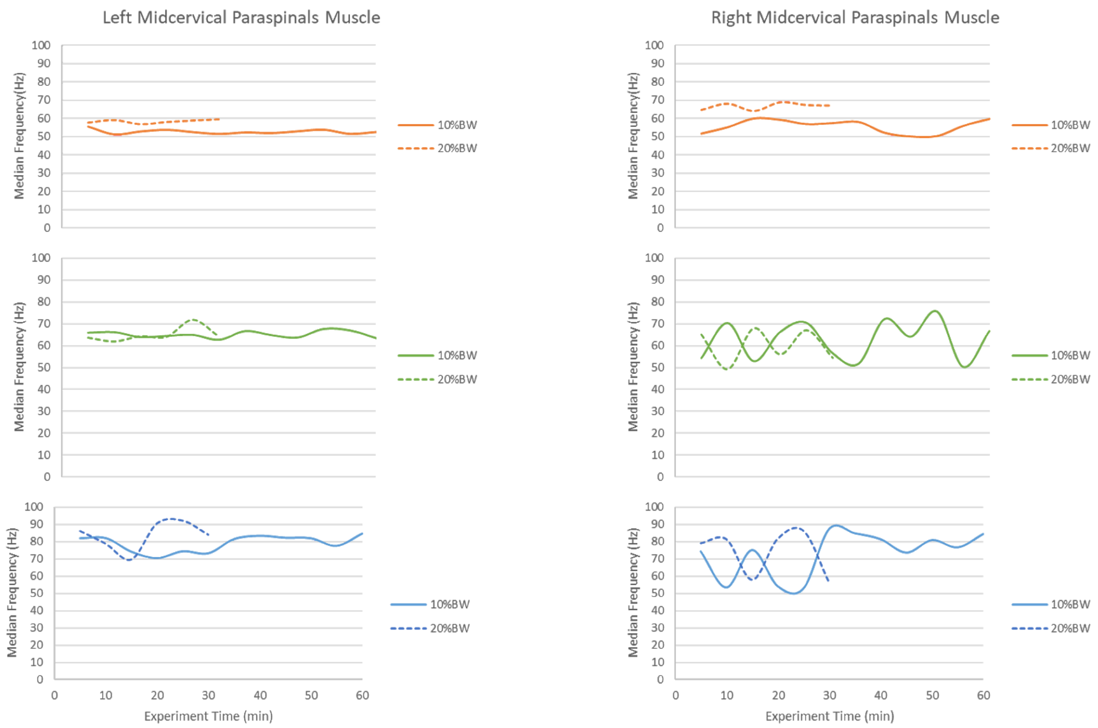

Right Erector Spinae
Median Frequency(Hz)
Median Frequency (Hz)
Experiment Time (min)
10%BW
20%BW


Left Lower Trapezius
Median Frequency(Hz)
Median Frequency (Hz)
Median Frequency (Hz)
10%BW
20%BW
10%BW
20%BW
10%BW
20%BW
Experiment Time (min)


RightLower Trapezius
Median Frequency(Hz)
Median Frequency (Hz)
Median Frequency (Hz)
10%BW
20%BW
10%BW
20%BW
10%BW
20%BW
Experiment Time (min)


Left Upper Trapezius
Median Frequency(Hz)
Median Frequency (Hz)
Median Frequency (Hz)
10%BW
20%BW
10%BW
20%BW
10%BW
20%BW
Experiment Time (min)


Right Upper Trapezius
Median Frequency(Hz)
Median Frequency (Hz)
Median Frequency (Hz)
10%BW
20%BW
10%BW
20%BW
10%BW
20%BW
Experiment Time (min)


Left Midcervical Paraspinals Muscle
Right Midcervical Paraspinals Muscle
Median Frequency(Hz)
Median Frequency (Hz)
10%BW
20%BW
Experiment Time (min)