A Preliminary Study on the Development of an Engineering Solution to Low Back Pain in Nurses

Undergraduate Senior Thesis

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Abstract

This study was completed by myself and a graduate student in the Mechanical and Aerospace Engineering (MAE) Department at the University of Alabama in Huntsville (UAHuntsville), Shushannah Smith, along with Dr. Dawn Bardot serving as advisor throughout the project. The purpose was to determine if there could be a viable engineering preventative solution to lower back pain in nurses. The first part of the study was a conducted survey to multiple types of nurses in practice. The survey asked many questions to determine if an engineering solution would be helpful or feasible to use in their everyday work. The experimental part of the study was be done in one of the Charger Hospital Nursing labs to determine the forces of three main muscles of the body: latissimus dorsi, rectus femoris, and biceps brachii. Electromyography (EMG) was used to measure the activity of these muscles while common maneuvers in the lab, such as turning a patient over and pulling the patient, were performed. This part of the study will be recorded using a video camera in the lab. This required the completion of a review with the Institutional Review Board (IRB).

The last part of the study was done in the Vicon Camera Lab in Technology Hall (TH) at UAHuntsville. This was done to recreate the movements recorded in Charger Hospital to determine certain angles the body creates when performing the same tasks. These results will not be directly compared to the results gained from the experiment performed in the Charger Hospital due to the difference in controlled variables. This will be later used to determine what type of device could be useful to the nurses without restricting the way they move on a day to day basis while performing common tasks. The information gained in this part of the study served more as exploratory data, and was used just in a supplementary manner, instead of complementary.

Introduction

According to the Lost-Worktime Injuries Report of 2003 from the United States Bureau of Labor and Statistics, registered nurses, nursing aides and other nursing personnel combined made up for a total of approximately 77,470 injuries in the workplace that required time off from work. Only one other categorical profession, material movers and laborers, combined to a greater number at 89,510 injuries that required time off from work. Of the injuries reported for nurses and nursing personnel, the injuries were predominantly related to the trunk of the body, and more specifically to the lower back on either side. These work-related injuries occurred mostly due to overexertion while lifting or moving patients. This is true as well for the movers and laborers, but for this study the focus was in nursing and nursing related fields (United States Department of Labor: Bureau of Labor and Statistics, 2005).

The injuries presented above cause problems for all parties involved. The hospital or clinic setting that the nurse works in will either lose money or lose efficiency. The administrators can choose to replace the worker, thus paying both the injured nurse and the replacement nurse, or they can choose to be short-staffed, therefore forcing fewer nurses to do the same amount of work and automatically cutting efficiency in the workplace. The most important problem, however, is the injured nurse, who now is in pain and out of the normal working routine. This is the problem this study focuses on. By finding a preventative solution for practicing nurses, the number of nursing injuries could be drastically lowered.

While working in a nursing related environment as well as discussing and surveying nursing personnel, it was easily discovered that the main problem in this environment is not that the nursing staff does not know the correct measures to take to prevent injuries to their lower back. The issue for nurses is overall convenience in serving the patient, and they are often

constrained by time. From observation, nurses tended to do what was needed to be done as efficiently and correctly as possible. With the "patient comes first" mindset nurses have, the effect of movements and positioning of their bodies is often not their most important objective. This led to the thought of a monitoring system that could be programmed to warn or alarm the nurse if the muscles in their back were obtaining more forces than safety allows. The device would be consistently worn throughout the work day, and would constantly run. This study shows a preliminary report on experimental projects to determine how the device could work and a survey of practicing nurses to determine if they would use such a device if it existed. A supplementary study is also discussed, to view the correct and incorrect positions of someone lifting.

Literature Review

To understand the problem of lower back pain in nurses, previous studies, experiments and literature on the subject were reviewed. Two main subjects in the literature were studied: the causes of lower back pain and devices created to help prevent lower back pain.

Causes of Lower Back Pain

Through research it was found that there was no single cause of back pain that can be singly identified. However, one statement that was obvious was that lower back pain was typically work-related (Sikiru, 2010). The disks that make up the spine convert loads that are axial into tensile loads, and the longer the annulus, a resistor to tensile loading, is subjected to these loads it becomes more likely to tear and can cause chronic low back pain. Often, the pain

can be relieved by activities other than lifting heavy objects or twisting the back, but the pain is recognized to be the worst when sitting or during pauses in activity (Keller, 1999).

Devices Created to Help Prevent this Problem

Over the years, once back pain was determined to be a true and consistent problem, solutions were sought after by researchers in the field. Helpful devices were designed to help prevent injuries in fields such as nursing. Such devices included the "Elevate and Transfer Vehicle" (ETV) created to transfer patients from one place to another (Le Bon & Forrester, 1997). Le Bon and Forrester determined that the patient handing devices, such as the ETV, would not cut down on lower back pain in nurses because they would not be used due to time constraints and personal preferences of the nurses. Another researcher noted that if the patient handling devices were used they would significantly cut down on back injuries that nurses experience (Zhuang, Stobbe, Hsiao, Collins, & Hobbs, 1999). Other devices were created as well, including a patient handling sling device (Elford, Straker, & Strauss, 1999). Wearable technology, devices much like the one this study aims to produce, has seen a significant rise in the last twenty (20) years and keeps improving. Electromyography (EMG) was often used in the study of the muscle activity in the back, similar to the discussed experiment in this preliminary study.

Methods and Experimentation

Survey

The survey was completed to determine the amount of interest that practicing nurses would have in a device that would monitor their body positioning and muscle activity. The

survey was implemented in an online anonymous survey site, www.surveymonkey.com, and sent

to both practicing nurses and retired nurses from Baptist Memorial Hospital in Memphis,

Tennessee. Twenty-two (22) nurses were surveyed with questions in the exact layout as shown

in the Appendix section of this report. All twenty-two (22) nurses responded completely to the

survey.

Charger Hospital Experiment

Charger Hospital, on the campus of the University of Alabama in Huntsville, serves as a

practicing facility for the nursing students on campus. Within Charger Hospital, Dr. Emil

Jovanov from the Department of Electrical and Computer Engineering has a physiology lab for

the students to use, as well as to perform research. In the physiology lab there are 2 sets of

cables and electrodes for electromyography (EMG) to measure the activity of muscles in the

body. One set of cables measures raw EMG, and the other set of cables measure the envelope

EMG. Each set includes a positive wire, a negative wire and a wire that is used as ground for a

total of three (3) wires.

Since this experiment was designed to measure the activity of three separate muscles, the

muscles were grouped in different configurations in order to retrieve a raw and an envelope

output for each muscle. Along with these configurations, the experiment was designed to show

the muscle activity for each muscle group when using a sliding device, a common medical

device used by nurses to move patients while on the bed, and without the use of the device.

Therefore, the experimental configurations were repeated twice to include both the use of the

device and the absence of the device. Together, eight (8) configurations were used in the

electromyography experiment. The configurations are listed at the end of this section of the
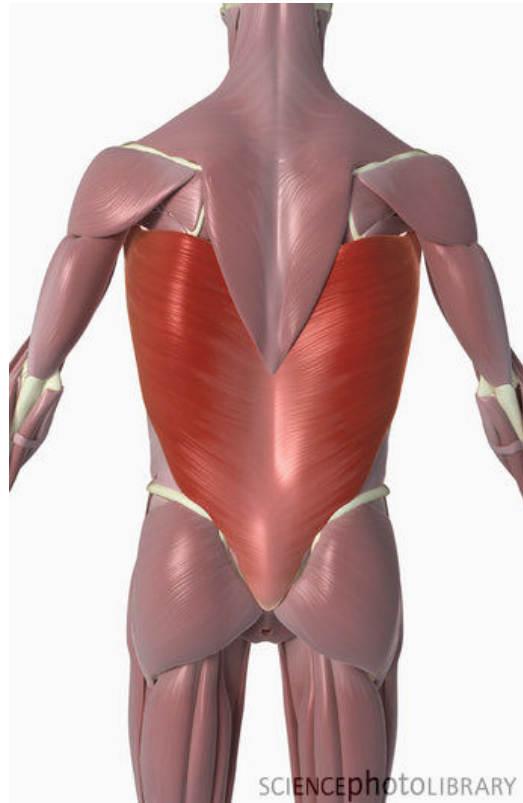
onstrate the process. The f

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Figure 1: Latissimus Dorsi

Figure 2: Rectus Femoris

Library). In Figure 3, both the biceps brachii and the triceps brachii are shown; however, the

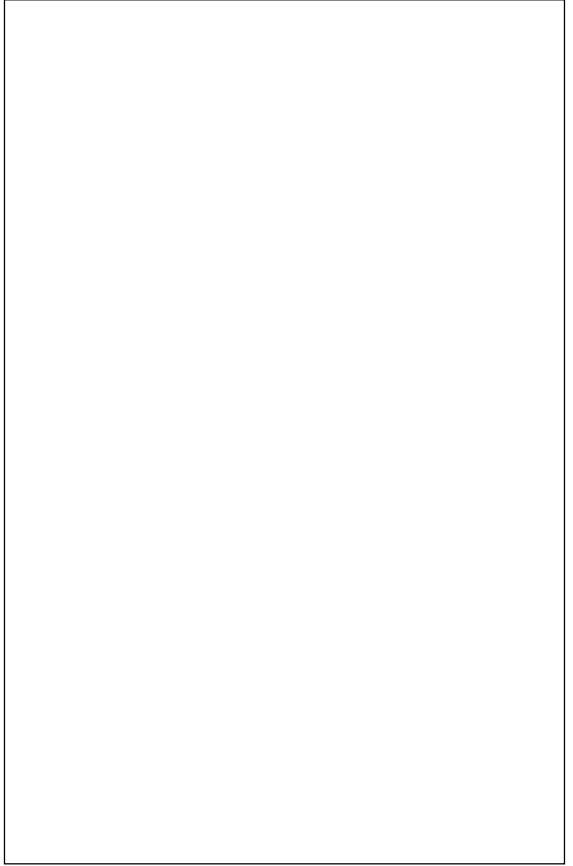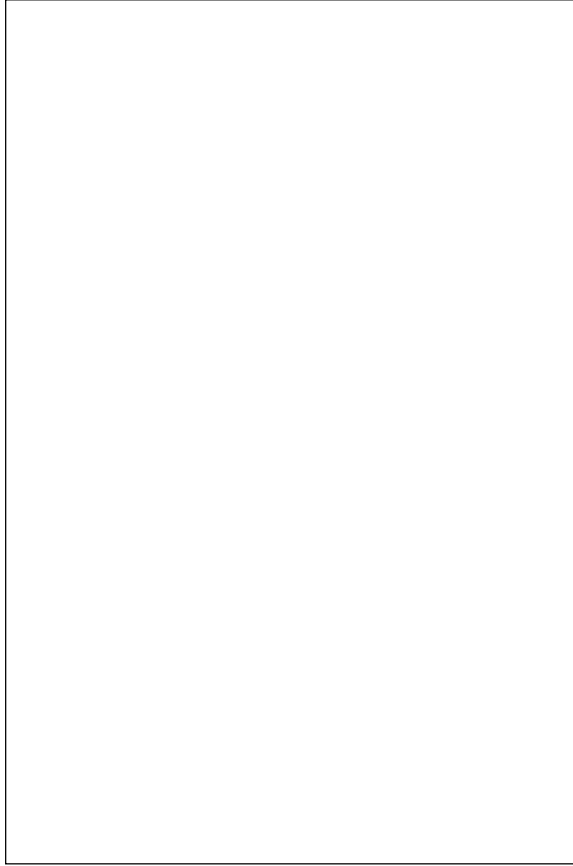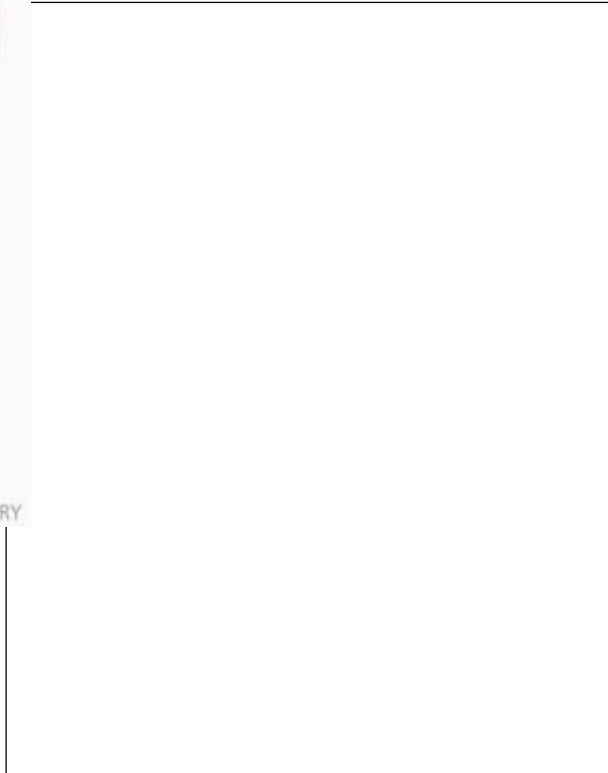only focus in this experiment was the biceps brachii muscle.

Figure 3: Biceps Brachii

The configurations below show the order in which the experiment was ran. For each configuration the same protocol was followed to have the least amount of bias, and greatest amount of controls. The following protocol was used:

Movement 1. Stand still at rest for ten (10) seconds

Movement 2. Perform pulling movement with no load (do not actually pull the patient)

Movement 3. Stand still at rest for ten (10) seconds

Movement 4. Perform pulling movement with load (actually pull patient either with or without sliding device)

*These movements were recorded by electromyogram as well as video camera

The following configurations were used:

Configuration 1 (with sliding device): rectus femoris (raw), latissimus dorsi (envelope)

Configuration 2 (with sliding device): latissimus dorsi (raw), rectus femoris (envelope)

Configuration 3 (with sliding device): latissimus dorsi (raw), biceps brachii (envelope)

Configuration 4 (with sliding device): biceps brachii (raw), latissimus dorsi (envelope)

Configuration 5 (without sliding device): biceps brachii (raw), latissimus dorsi (envelope)

Configuration 6 (without sliding device): latissimus dorsi (raw), biceps brachii (envelope)

Configuration 7 (without sliding device): latissimus dorsi (raw), rectus femoris (envelope)

Configuration 8 (without sliding device): rectus femoris (raw), latissimus dorsi (envelope)

Vicon Camera Lab

Technology Hall at the University of Alabama in Huntsville is home to multiple

departments within the college of engineering as well as computer science. Also residing in

Technology Hall is the Automated Tracking Optical Measurement (ATOM) Lab, directed by Dr.

Nathan Slegers in the Department of Mechanical and Aerospace Engineering. The

supplementary study mentioned in the Introduction section of this report took place in this lab,

where 33 Vicon IR cameras are placed as shown in Figure 4 around the ceiling of the lab (UAH:

College of Engineering).

The ATOM Lab was used in this study strictly as extra knowledge to see the viable

options that would work for future research in creating a device to help prevent lower back pain.

The video taken from the Charger Hospital physiology lab experiment was used to reenact the

movement of pulling a patient on a bed to show two extremes of how it could be done. The first

extreme was pulling the patient without hardly any bending at all, and the second extreme was

bending all the way over the patient to move them. The data from this experiment included the

output of the cameras in the lab in picture form, as you will see in the Findings section of this

report, as well as movement data in the form of position, velocity and acceleration. The raw data

was collected in Microsoft Excel and will be kept and studied further in the next step of the
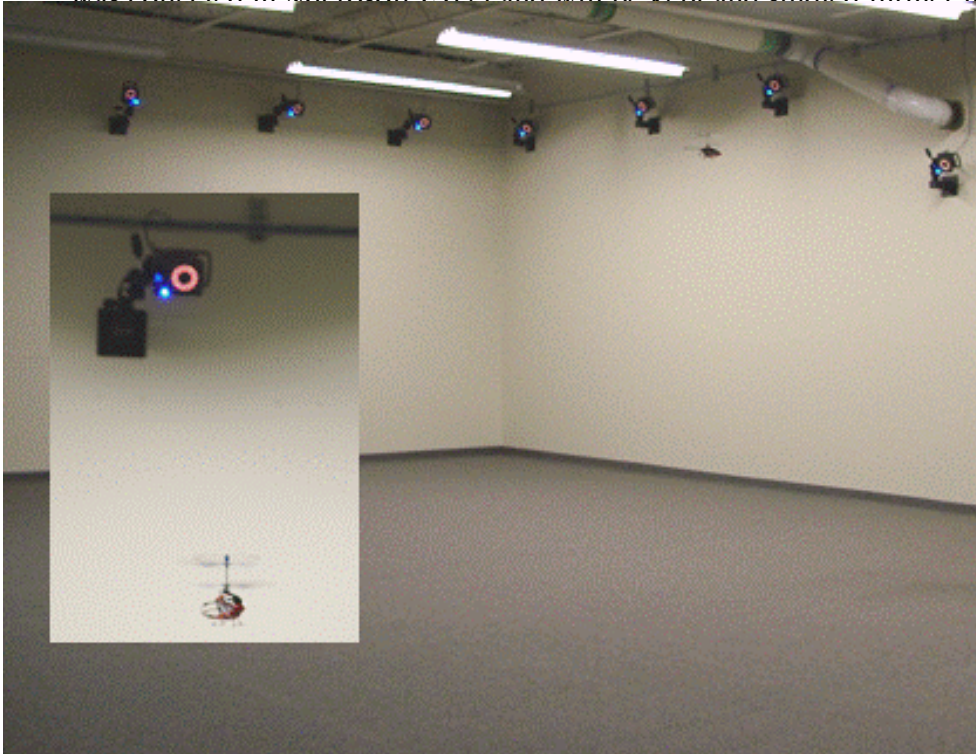
Figure 4: ATOM Lab

Findings

The findings below show the results from the surveying of twenty-two (22) nurses to determine

the feasibility and usability of a wearable alert device during the work day.

Demographics

Occupation					
	Student Nurse	Practicing Nurse	Retired Nurse	Other Health Professional	Response Count
Select the appropriate option.	0.0% (0)	90.9% (20)	9.1% (2)	0.0% (0)	22

Years							
	1 year	2 years	3 - 5 years	5 - 10 years	10 - 20 years	20+ years	Response Count
Select the appropriate option.	0.0% (0)	0.0% (0)	18.2% (4)	9.1% (2)	27.3% (6)	45.5% (10)	22

General Rating Questions

My patient's safety is priority above my own safety.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
Select a rating.	0.0% (0)	0.0% (0)	27.3% (6)	40.9% (9)	31.8% (7)	4.05	22

Maintaining the correct posture during my day-to-day work is important to me.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
Select a rating.	0.0% (0)	0.0% (0)	0.0% (0)	68.2% (15)	31.8% (7)	4.32	22

I expect to experience job-related low back pain at some point in my career.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
Select a rating.	4.5% (1)	22.7% (5)	4.5% (1)	22.7% (5)	45.5% (10)	3.82	22

I am aware of preventative measures that I can take to avoid low back pain.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
Select a rating.	0.0% (0)	0.0% (0)	0.0% (0)	77.3% (17)	22.7% (5)	4.23	22

I plan to take measures to help prevent low back pain.

|	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
Select a rating.	0.0% (0)	0.0% (0)	4.5% (1)	59.1% (13)	36.4% (8)	4.32	22

I would appreciate an alert system that would let me know if I was about to harm my lower back.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
Select a rating.	0.0% (0)	4.5% (1)	4.5% (1)	50.0% (11)	40.9% (9)	4.27	22

General Choice Questions
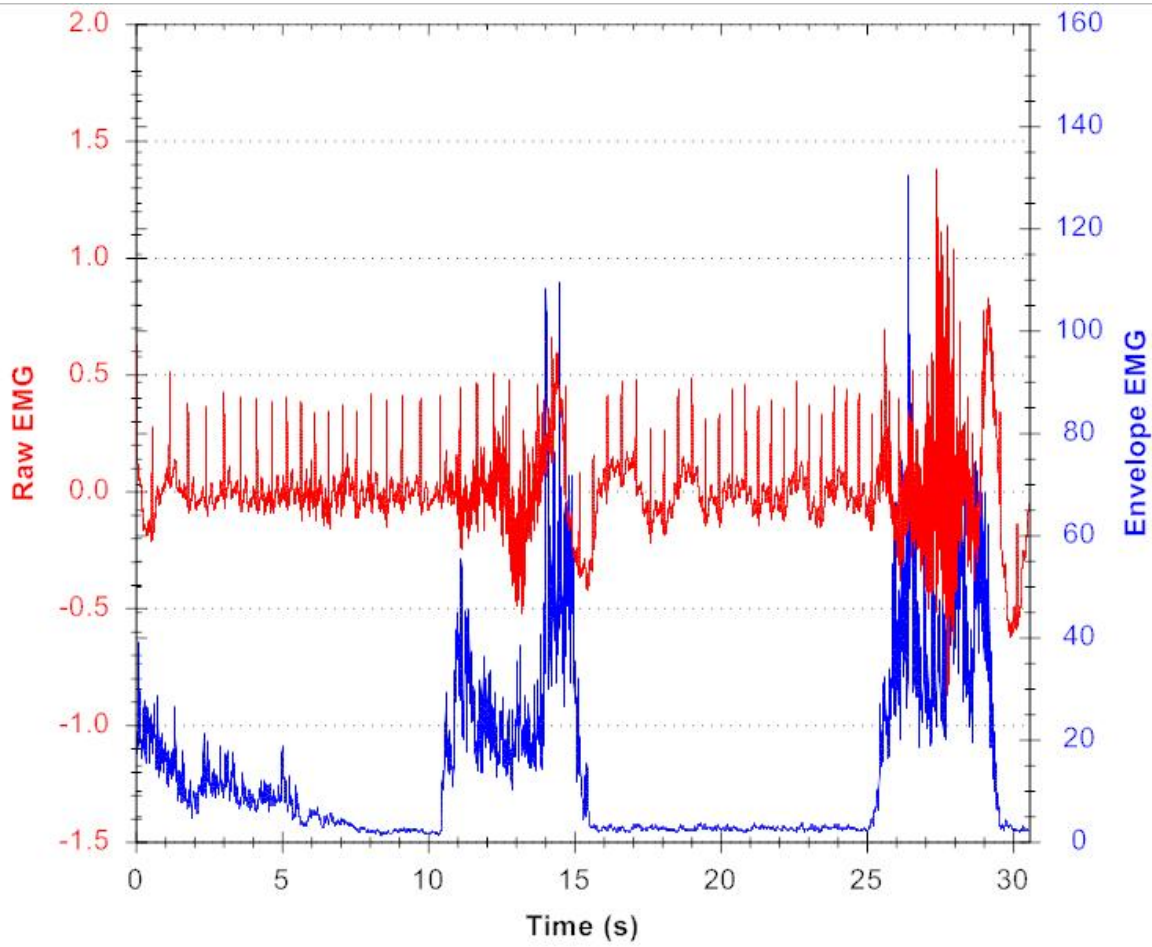
I would prefer an alert system to be...

	Response Percent	Response Count
suitable for wearing (i.e. attached to/located on your body and goes where you go).	68.2%	15
stationary (i.e. remains in patient's room).	0.0%	0
I have no preference.	31.8%	7
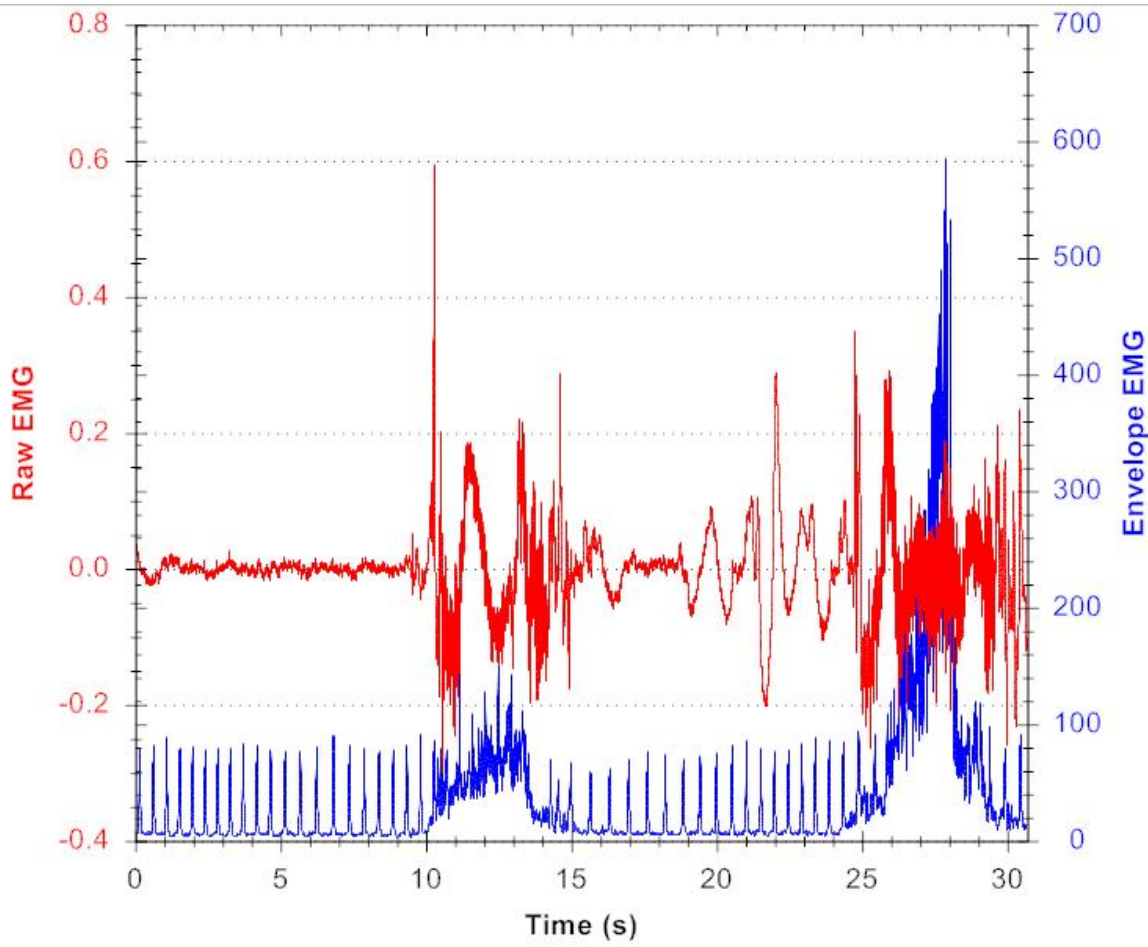
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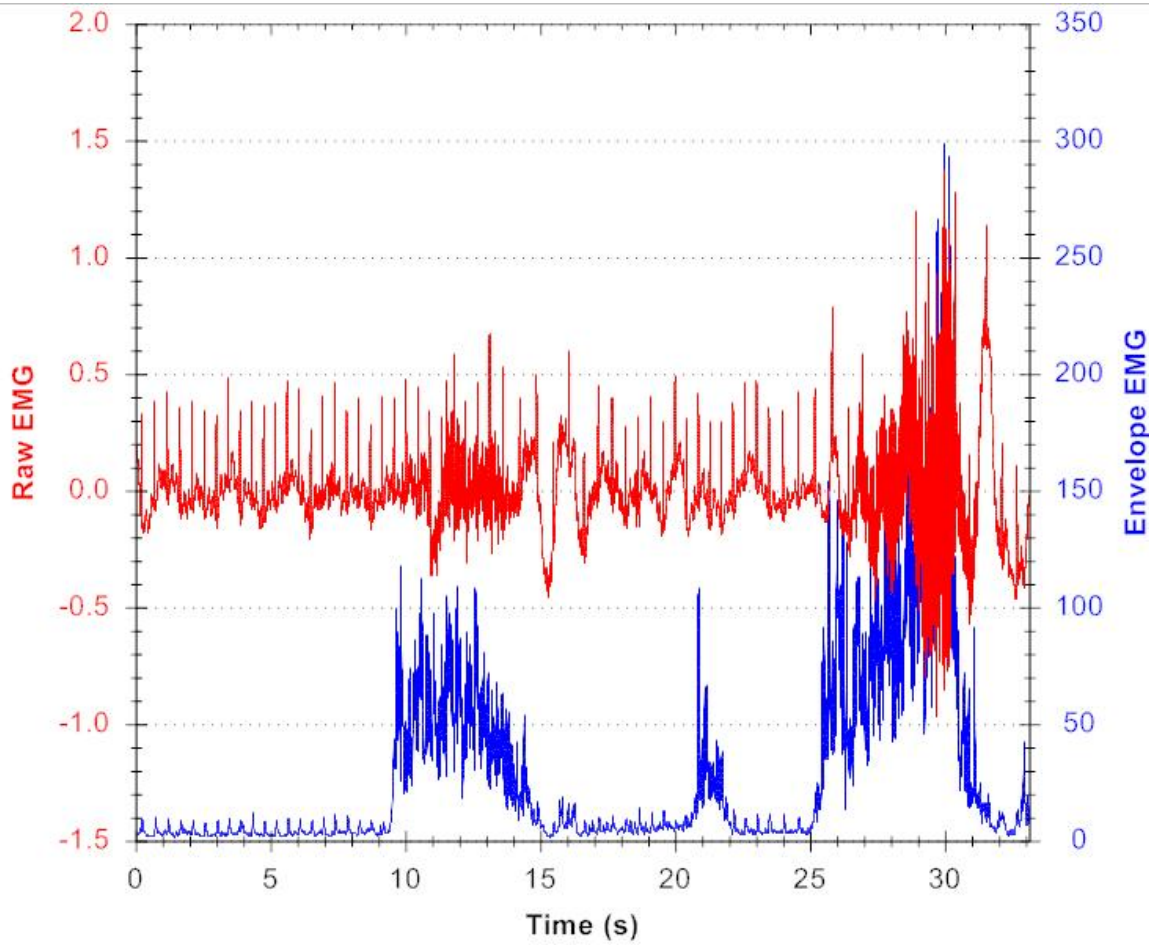
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Figure 5: Configuration 1

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Figure 6: Configuration 2

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Figure 7: Configuration 3

Figure 7 above shows the output for Configuration 3. Paying attention to only the

envelope EMG output, a medium-sized spike is noticed to start around ten (10) seconds. This

represents the pulling movement with no load after the ten seconds of rest at the beginning.

Beginning at twenty-five (25) seconds, an only slightly larger peak begins. This represents the

pulling of the actual patient (with load). There is also a small spike around twenty-one (21)

seconds that just shows extraneous movement outside of the span the experiment is looking for.

This shows little significant difference between the activity with no load and the activity with
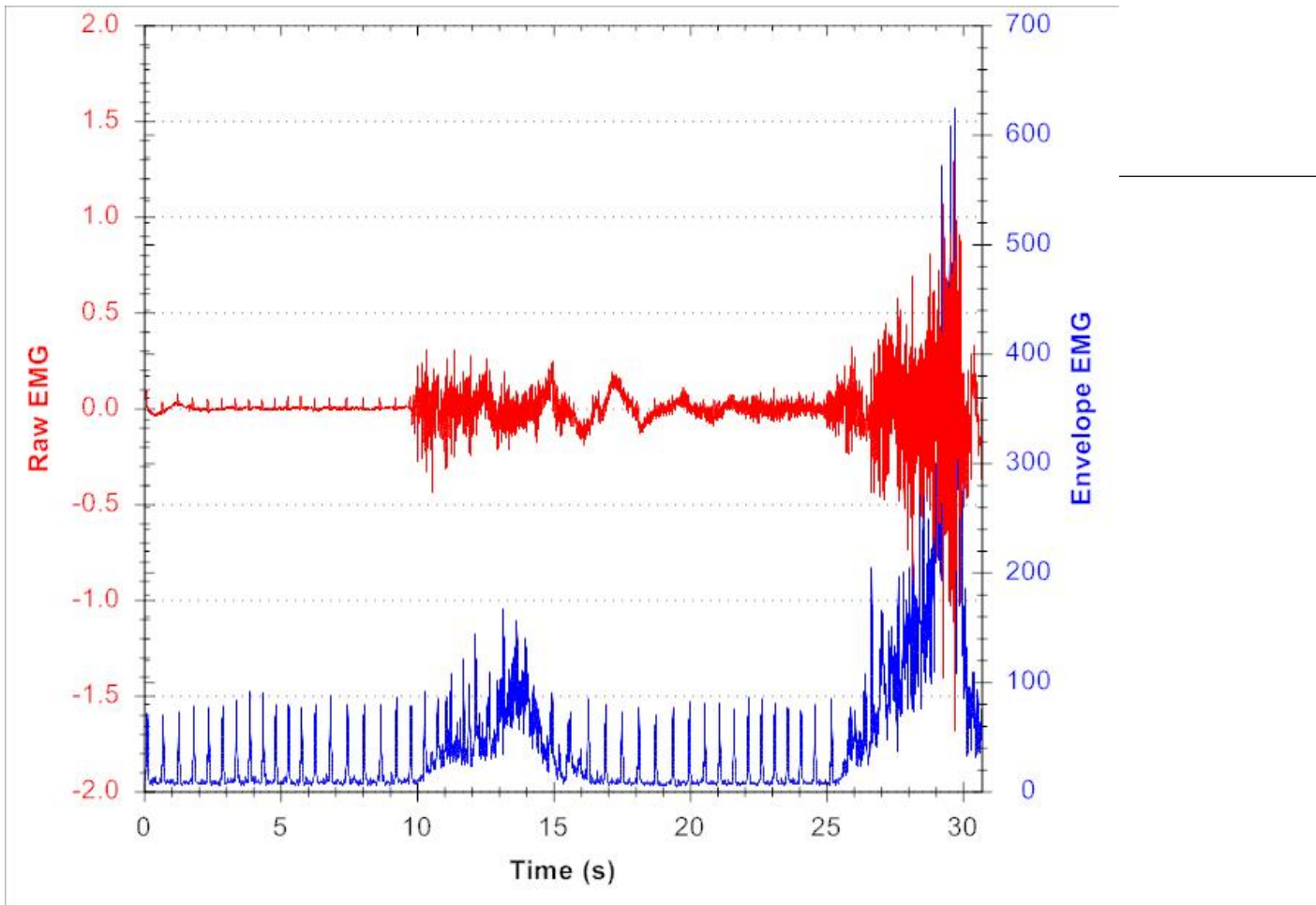
Figure 8: Configuration 4

Figure 8 above shows the output for Configuration 4. Paying attention to only the envelope EMG output, a small spike is noticed to start around ten (10) seconds. This represents the pulling movement with no load after the ten seconds of rest at the beginning. Beginning at twenty-five (25) seconds, a larger peak begins. This represents the pulling of the actual patient (with load). This shows a small significant difference between the activity with no load and the activity with load.
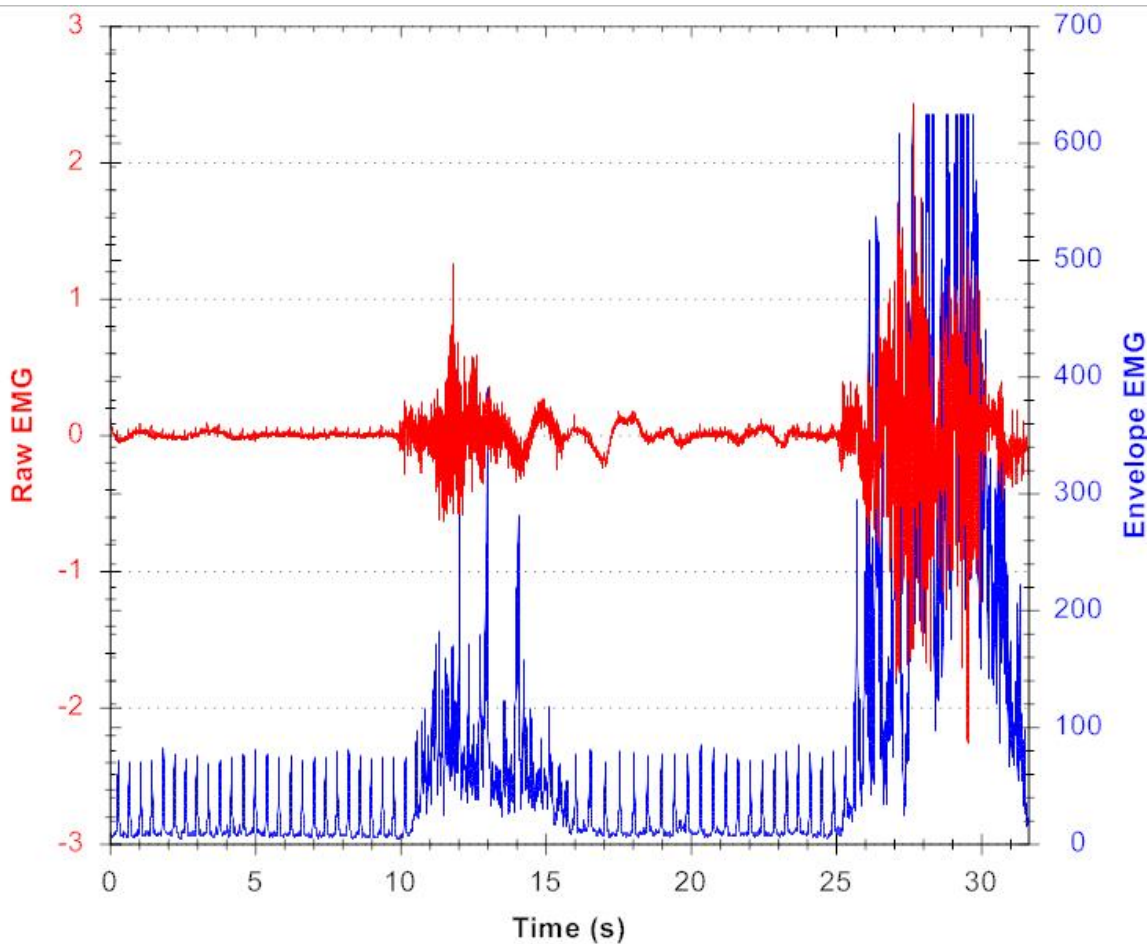

Figure 9: Configuration 5

Figure 9 above shows the output for Configuration 5. Paying attention to only the

envelope EMG output, a small spike is noticed to start around ten (10) seconds. This represents

the pulling movement with no load after the ten seconds of rest at the beginning. Beginning at

twenty-five (25) seconds, a much larger peak begins. This represents the pulling of the actual

patient (with load). This shows significant difference between the activity with no load and the
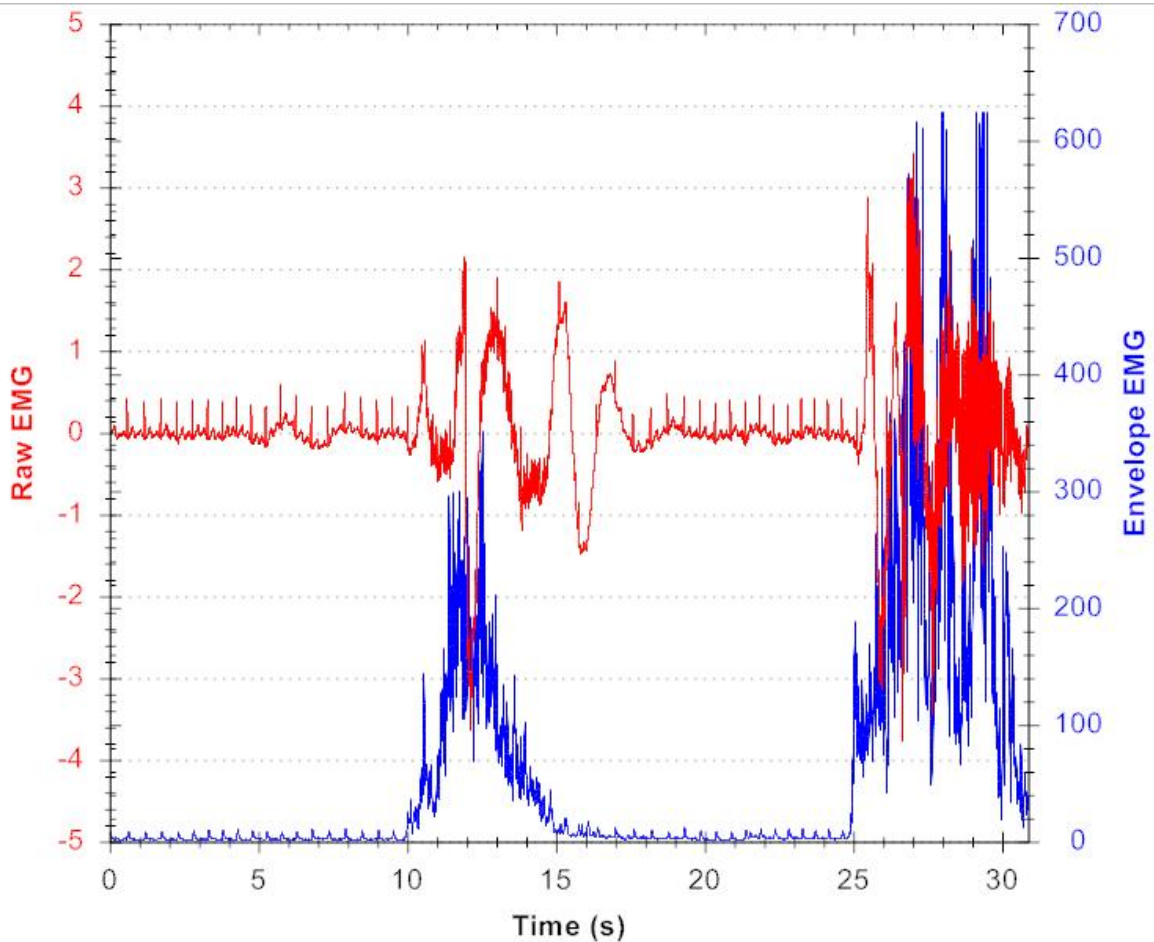

Figure 10: Configuration 6

Figure 10 above shows the output for Configuration 6. Paying attention to only the envelope

EMG output, a medium-sized spike is noticed to start around ten (10) seconds. This represents

the pulling movement with no load after the ten seconds of rest at the beginning. Beginning at

twenty-five (25) seconds, an only slightly larger peak begins. This represents the pulling of the

actual patient (with load). This shows little significant difference between the activity with no
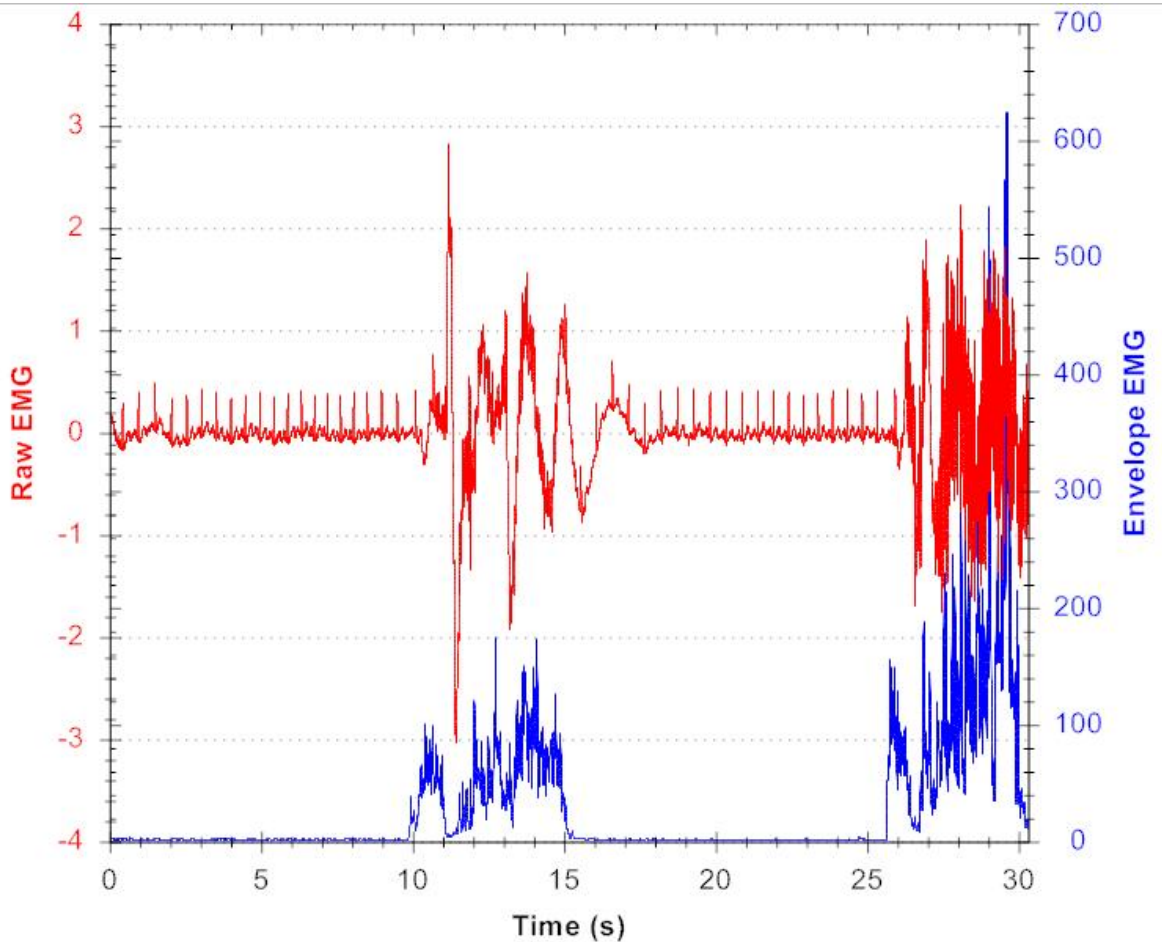

Figure 11: Configuration 7

Figure 11 above shows the output for Configuration 7. Paying attention to only the envelope EMG output, a small spike is noticed to start around ten (10) seconds. This represents the pulling movement with no load after the ten seconds of rest at the beginning. Beginning at twenty-five (25) seconds, a much larger peak begins. This represents the pulling of the actual patient (with load). This shows significant difference between the activity with no load and the activity with load.
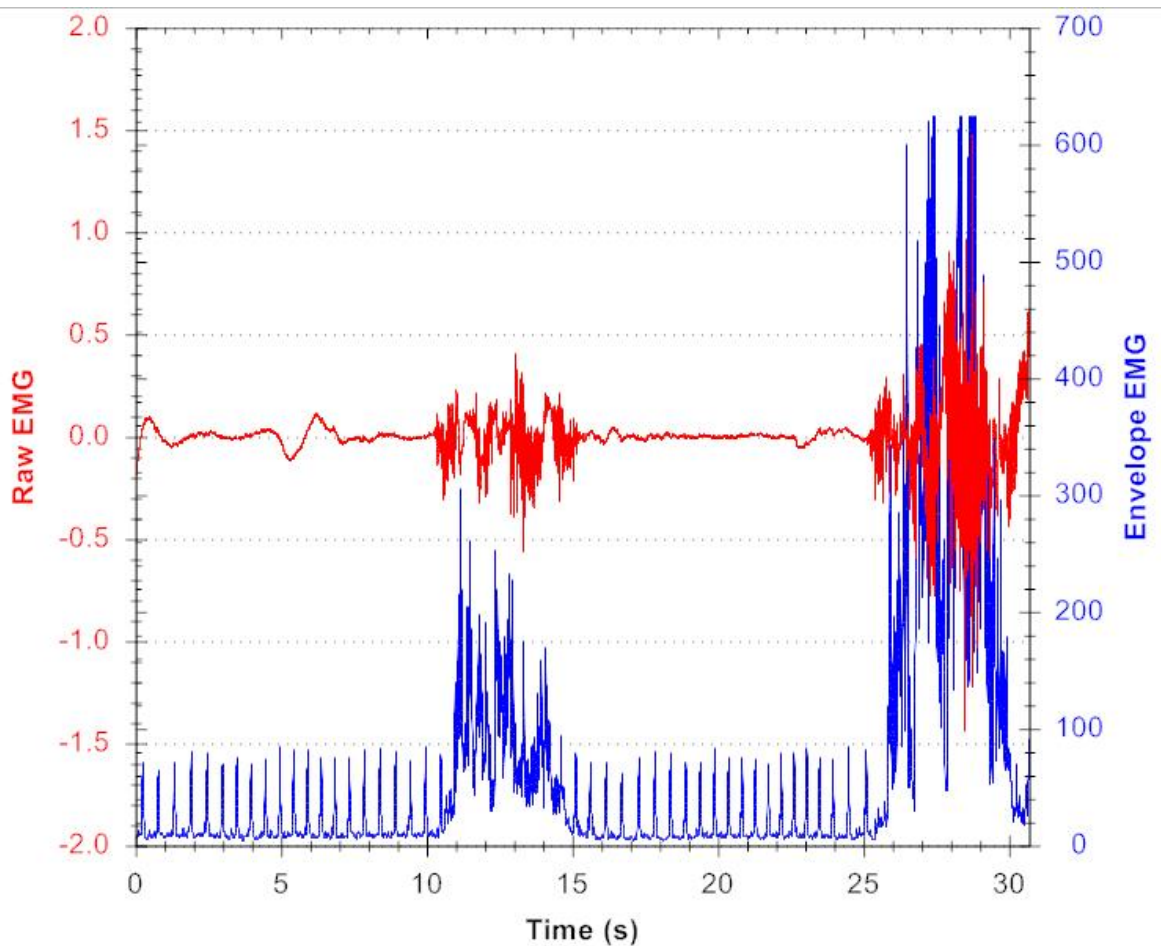

Figure 12: Configuration 8

Figure 12 above shows the output for Configuration 8. Paying attention to only the envelope EMG output, a small spike is noticed to start around ten (10) seconds. This represents the pulling movement with no load after the ten seconds of rest at the beginning. Beginning at twenty-five (25) seconds, a larger peak begins. This represents the pulling of the actual patient (with load). This shows significant difference between the activity with no load and the activity with load.

Vicon Camera Pictures

Emphasis on bending too far over patient
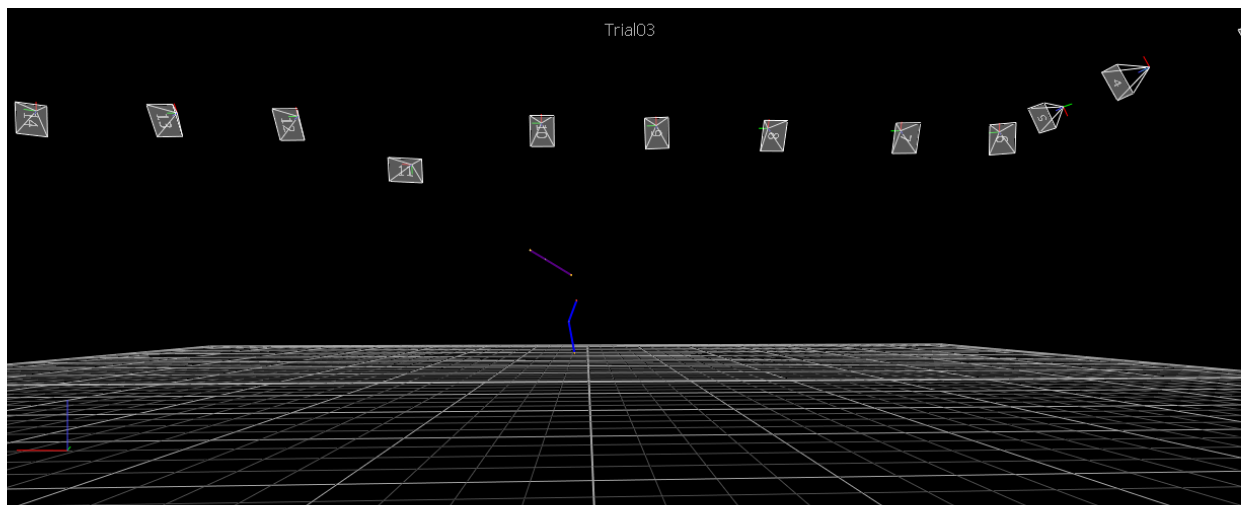
Emphasis on using little to no back in pulling patient
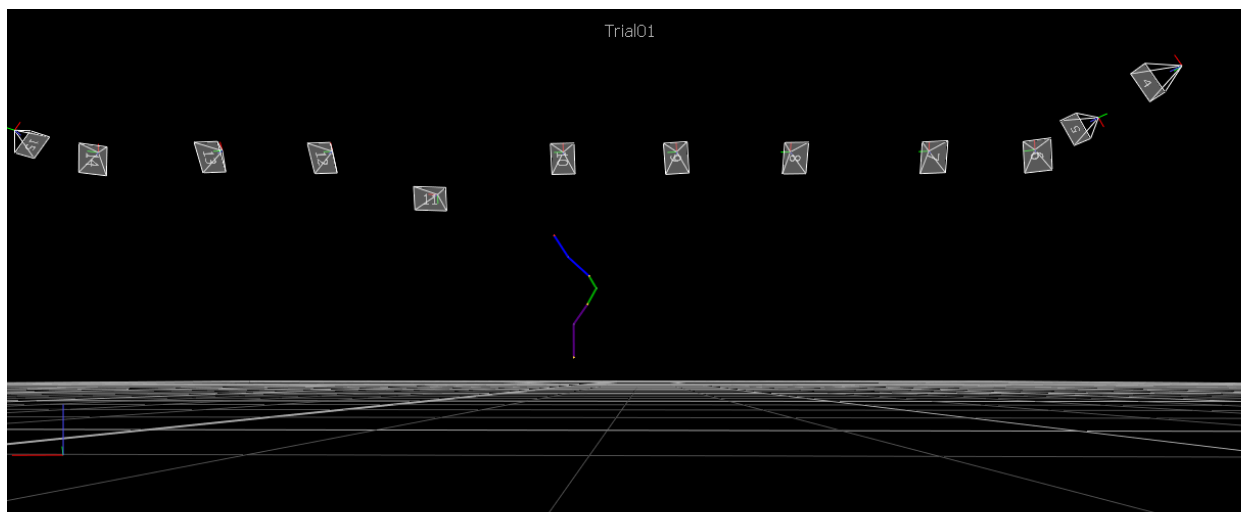
These pictures from the Vicon cameras in the ATOM Lab will be used in further study after this preliminary study is complete. They will help in finding the angles between the latissimus dorsi back muscles and the rectus femoris thigh muscles to demerine coreect positioning.

Discussion

The findings from the survey show a significant interest in a product or device that could possibly help prevent lower back pain in nursing. It was determined that the best solution would be a wearable device that would run constantly throughout the day in order to alert the nurses when improper use of the back is occurring or close to occurring.

The results from the main experiment in Charger Hospital show a sign that the activity in the back is mostly due to the amount of loading put on the back instead of the way in which you move as previously thought. Positioning your body correctly depends on the amount of load, or amount of mass that will be lifted or pulled. The biceps brachii muscles tended to show significant activity with any movement, but it is understood that the bicep muscle placement is not often an issue, and can often handle more stressful positions than can the lower back muscles. The rectus femoris muscles in the legs also show a significant difference in the loading and lack of loading that occurs. However, the leg muscles and thigh muscles are designed to take more stresses and strains than the lower back muscles. With this determination, moving forward with the research the only muscle group that will be monitored will be the latissimus dorsi muscles on either side of the back. Future research will also include more data from the ATOM lab to determine problems in positioning and body angles.

Acknowledgements

I would like to thank Shushannah Smith, a PhD. student at the University of Alabama in Huntsville, and my advisor, Dr. Dawn Bardot, for giving me guidance through this process and in experimental design and implementation. I am very appreciative to Dr. Emil Jovanov, Dr. Nathan Slegers and Mladen Milosevic, a graduate assistant to Dr. Jovanov, for supporting this project through the use of their labs and through the volunteering of their time. I would lastly like to thank Ms. Beth Wilson and Dr. Harry Delugach in the Honors College Office for their full support and help throughout this endeavor.

Resources

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Appendix

The following questions are the survey questions asked to the group of practicing and retired nurses. The survey was implemented online for easy access. The website used was www.surveymonkey.com. The survey link was emailed and every response was completely anonymous.

Choose the best response to the following questions:

1. What is your occupation?
   a. Student Nurse
   b. Practicing Nurse
   c. Retired Nurse
   d. Other (please specify)

2. How long have you held the above position (if retired, how long did you practice nursing?)
   a. 1 year
   b. 2 years
   c. 3-5 years
   d. 5-10 years
   e. 10-20 years
   f. 20+ years

Select the most appropriate rating – 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree) or 5 (strongly agree) – for each of the following statements:

3. My patient's safety is priority above my own safety.

4. Maintaining the correct posture during my day-to-day work is important to me.

5. I expect to experience job-related low back pain at some point in my career.

6. I am aware of preventative measures that I can take to avoid low back pain.

7. I plan to take measures to help prevent low back pain.

8. I would appreciate an alert system that would let me know if I was about to harm my lower back.

Choose the best response for the following questions:

9. I would prefer an alert system to be

     a. Suitable for wearing (i.e. attached to/located on your body and goes where you go)
     b. Stationary (i.e. remains in patient's room)
     c. I have no preference

10. I would prefer an alert system function
     a. Continuously (i.e. always running and aware)
     b. As needed (i.e. only when turned on or only in certain locations)
     c. I have no preference