ABSTRACT

Quantitative assessment of improvements in posture from therapeutic riding on a mechanical horse simulator

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Individuals with neuromuscular disabilities are commonly treated with therapies that involve repetitive motion of the body and limbs. Therapists have utilized this type of therapy with live horses for years and although it has many benefits there are factors such as allergies, weather, and accessibility that can hinder a patient from receiving equine-assisted therapy (EAT). Researchers at Baylor University have developed a mechanical horse-riding simulator (MHS) to address this need and to provide a platform to research the benefits of EAT. The purpose of this thesis research was to quantitatively assess improvements in trunk posture and stability from riding on the MHS. A multi-camera motion capture system was used to record markers on the back, neck, and shoulders of individuals treated on the MHS at an accredited therapy clinic. Results show that trunk angle variation observed after riding the MHS was less than baseline measures observed before riding.

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QUANTITATIVE ASSESSMENT OF IMPROVEMENTS IN POSTURE FROM THERAPUETIC RIDING ON A MECHANICAL HORSE SIMULATOR

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DEDICATION

Shannise, thank God someone in the family knows how to spell and has good grammar, otherwise I don't think anyone would understand this. Thank you for being there for me and just being your crazy self, love you and wouldn't trade you for the world.

Luther, my lu lu or should I say Dr. Sintim. Without your diagnosis and advice God knows I would not have finished this, I love you so much, I hope one day I can help people , like how you do every day.

Mommy and Daddy, I love you so much. Thank you for believing me even when I didn't believe in myself and for reminding me that God loves me and has a plan for me in my life. Thank you for always being there for me, we are almost there! Remember we are graduating together.

CHAPTER ONE

Introduction

Purpose of Therapy

The goal of physical therapy is to help the particular client achieve the highest functional outcome. Depending on the parameter that one wants to improve, be it the gait, mobility, balance, or social capabilities of the patient, one can find the best application of therapy in order to achieve the highest functional outcome. Therapy can be classified into two different major categories, physical and psychological.

Psychological Therapy

Different types of psychological therapy include psychoanalytic and cognitive-behavioral therapy. Patients requiring psychoanalytic therapy usually have regular sessions with a psychiatrist who listens to them talk about their life. Psychiatrists also look for patterns or significant events that may play a role in the client's current position [5]. The purpose of this type of therapy is to provide an environment where the client can feel safe in revealing feelings or actions that have led to stress or tension in their lives. It has been proven that sharing these burdens with another person can have a beneficial influence on the patient's life [5].

Cognitive-Behavior therapy is often used for patients with depression or anxiety. The purpose of this type of psychological therapy is to change the thought patterns of the patient that may contribute to problematic behaviors. Usually the problematic

behaviors exhibited by the client/patient have become habit from years of training or are from a predisposition. Cognitive-Behavioral Therapy can be very effective for treating specific problems such as arachnophobia, the fear of spiders. The therapist may gradually expose the patient to the phobia until it diminishes or fades away [5].

Physical Therapy

Most patients in need of physical therapy are suffering from some type of orthopedic, geriatric, cardiovascular, or neurological disorder or injury. Each type of physical therapy focuses on a specific area in the body; this makes it easier for the therapist to make plans to meet each specific goal that the client may wish to reach. In order to understand each form of physical therapy one must know the causes, goals and outcomes of each therapy.

Orthopedic therapy focuses on the muscular and skeletal systems. Orthopedic physical therapists diagnose and treat injures and disorders involving the muscular and skeletal systems including rehabilitation before or after orthopedic surgery. Some examples of different injuries that orthopedic physical therapists are accustomed to are fractures, strains, sprains, spinal conditions, amputations, arthritis, and different sports related injuries. The goal of orthopedic therapy is to provide a thorough musculoskeletal evaluation from which comprehensive treatment goals and plans of care are developed and customized to each client's condition [9].

Geriatric physical therapy is therapy specifically for aging seniors. This type of therapy usually covers a wide area of issues that older adults deal with, including

osteoporosis, Alzheimer's disease, and hip and joint replacements. The Center for Disease Control and Prevention has reported that one-third of all people over the age of sixty-five fall every year, making falls the leading cause of injury for older adults. Many older adults experience falls and resulting hip fractures every year. Approximately twenty-percent die within a year due to the injury and a number of the remaining eighty-percent do not return to their previous level of functioning. Physical therapy can help older adults to remain strong and independent, as well as productive. The primary goal is to create healthier and more active lifestyles for older adults by restoring mobility, increasing fitness levels, and reducing pain [10].

Cardiovascular physical therapists help clients with cardiopulmonary disorders or clients who have had cardiac or pulmonary surgery. Not every patient who suffers from a cardiovascular disease or injury is eligible for therapy. For some patients the risk of further injury is higher when it comes to engaging in therapeutic activities involving medium to intense exercise. The objectives of cardiovascular physical therapy are to reduce the pathophysiologic and psychosocial effects of heart disease, limit the risk for death, relieve cardiac symptoms, and reintegrate heart disease patients into their families and in society as healthy and independent individuals [11].

There are many different modes of therapy available for patients with neurological disorders, each mode incorporates motor practice and the repetition of cyclic motions. Each mode is important for the establishment, development, reinforcement, and improvement of neural and motor pathways which in turn means

improvement in flexibility and movement in the muscles of patients with neurological disorders [1]. Therapeutic interventions that emphasize repetitive practice of skilled activities or cyclic motions such as walking may be helpful for many types of neurological disorders including those associated with cerebral palsy, stroke, and other central nervous system disorders.

Before entering physical therapy most clients develop goals or some kind of desired outcome they wish to achieve. Some may wish for better posture or a better gait, or to have less trouble standing up straight without swaying one way or the other. For parameters like gait and posture, how can one prove that someone exhibits improvement after therapy? The idea of measuring improvement in this circumstance seems highly subjective. Based on sight one person may think that there was some infinitesimal change while another could argue otherwise. For example one observer may say that the patient does not sway as much as they did before therapy as they sit or stand, while another may not notice the same difference. Does it qualify as improvement if a client, for example, can take more steps than they could a day before? Or that their posture is more centered on the frontal and medial anatomical plane? In other words they tend to sway less. Who decides if there was enough improvement and how does one quantify improvements like these?

Thesis Overview

This thesis project was completed in compliance with the requirements of the honors program at Baylor University. The objective of this thesis is to utilize quantitative

measures for the assessment of a program of therapy involving the use of a mechanical horse simulator (MHS). Topics discussed in the second chapter of this thesis are the different neurological/neuromuscular disorders, diseases and treatments that are used, including Equine-Assisted Therapy (EAT). The third chapter of this thesis will include a comparison of EAT to mechanical horse simulators, the examples of present designs of mechanical horse simulators (including one at Baylor University in 2013), and the modes of measuring improvement. The fourth chapter will describe the methods used in this study to quantitatively assess therapy on the MHS. The fifth chapter will consist of the results of the study, discussion and concluding remarks. The success of this honors thesis work will result in an objective, quantitative method of assessment of the mechanical horse simulator for the purpose of therapy of individuals with neuromuscular disabilities and in a pilot case study involving a single client.

CHAPTER TWO

Background and Previous Research

Types of Neurological Disorders

Neurological disorders cause the systematic dysfunction or disruption of anatomy functionality, and/or organic disorders of nerves and the nervous system. There are a broad range of neurological disorders and each can be treated using different forms of therapy.

Brain Tumors are one of the most life threatening forms of neurological disorders. After a successful treatment of chemotherapy, biological therapy, surgery, or radiation therapy, each client goes through a rehabilitation process. This process may consist of physical therapy to regain mobility, physical strength, and coordination. Occupational therapy can be used to help the client reintegrate back into society and daily living, or speech therapy can be used to address any problems with speech, language, hearing, or swallowing. [12]

Cerebrovascular disease is any disorder that affects the blood vessels that provide oxygen rich blood to a person's brain and face. The most well-known cerebrovascular disorder is stroke. Therapists help stroke survivors relearn skills that are lost when part of the brain is damaged. Therapists also teach survivors new ways of performing tasks to circumvent or compensate for any residual disabilities.

Parkinson's disease is a progressive disease of the nervous system marked by tremor, muscular rigidity, and slow, imprecise movement. Exercise can help improve gait, balance, tremor, flexibility, grip strength and motor coordination in people with Parkinson's disease or in people with any other form of movement disorder. [12]

Neuromuscular disorders such as multiple sclerosis, cerebral palsy, and muscular dystrophy affect the nerves that control the voluntary muscles, the muscles that one can control, such as the muscles in one's limbs. When the neurons become unhealthy or die, communication between the nervous system and muscles breaks down. As a result, the muscles weaken and waste away. The weakness can lead to twitching, cramps, aches and pains, and joint and movement problems. Sometimes it also affects heart function and the ability to breathe. [14]

One of the most important elements in any program of physical therapy is repetitive practice. Physical therapy emphasizes practicing isolated movements, repeatedly changing from one kind of movement to another, and rehearsing complex movements that require a great deal of coordination and balance. Physical therapists frequently employ selective sensory stimulation to encourage the use of impaired limbs and to help survivors regain awareness of stimuli on the neglected side of the body. [13] In the upcoming topics of this thesis the focus will be on neuromuscular and movement disorders, particularly with children.

Different types of Neurological Treatment

There are many different therapies and surgeries that can maintain muscle strength including tendon release, dorsal rhizotomy, baclofen, and equine-assisted therapy (EAT).

Tendon release is a surgical procedure that is used to cut through or disconnect a tendon. The procedure normally involves cutting the tendon and allowing it to retract towards the junction of the muscle and tendon [17, 18].

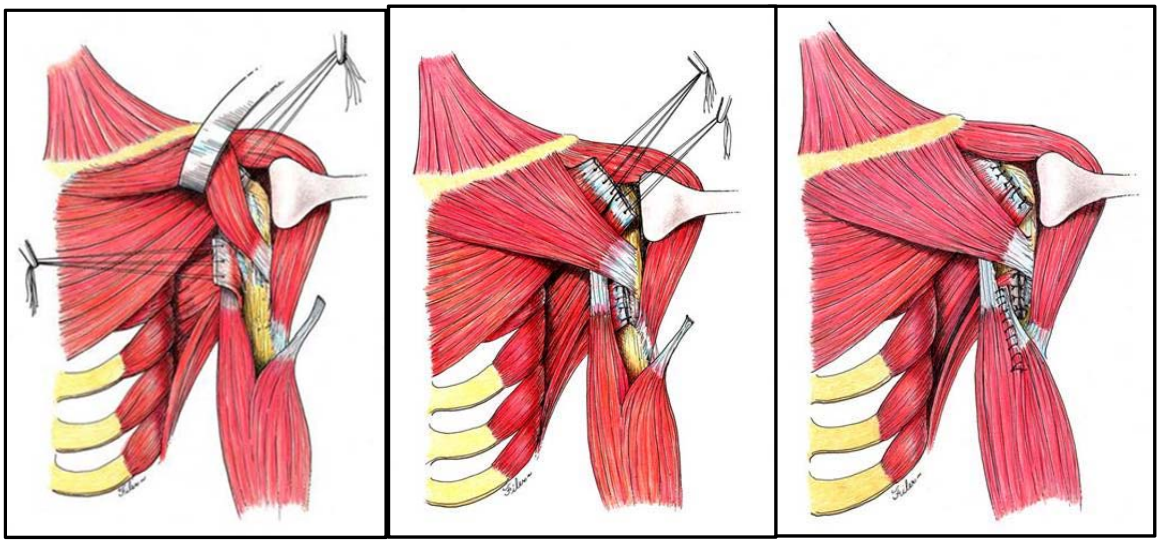


Figure 1. The tendon of the sternal head, which inserts to the humerus underneath the clavicular head, is carefully dissected and sharply released from the bone humerus. [21]

A patient might need to receive surgery to have a tendon released in order to remove an area of the tendon or other unhealthy tissue that may be causing problems with the muscle or with other tissues that restrict the movement of the patient. Tendon release can also be performed to relieve tightened or shortened muscles, to decrease friction irritation, or allow relaxation of joints especially in patients with cerebral palsy [17].

This remedy, for the most part, is effective for relieving patients from pain and making movement easier, yet there are still a few disadvantages that may occur from surgically releasing a tendon. Complications like wound infections, adhesions or numbness or tingling close to the surgery are possible side effects of tendon release.

Dorsal rhizotomy or selective dorsal rhizotomy (SDR) is a neurosurgical procedure that selectively destroys problematic nerve roots in the spinal cord. This type of treatment is used primarily to treat children with lower-extremity spasticity, also known as spastic diplegia or diparesis or spastic cerebral palsy.

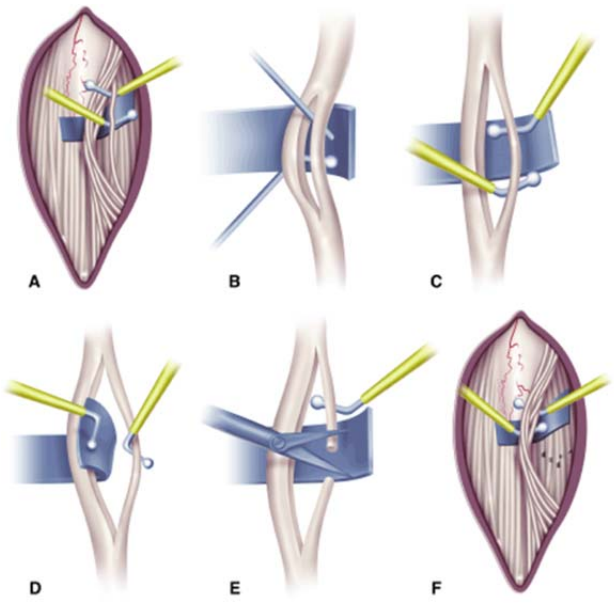


Figure 2. Selecting nerve roots from the spinal cord to remove [22].

The primary goal of SDR is to reduce spasticity and to improve lower-extremity function. Some advantages of SDR include reduced risk of spinal deformities in later years, decreased post-rhizotomy motor weakness, reduced hip flexor spasticity by sectioning the first lumbar dorsal root, shorter-term, less intense back pain, and earlier resumption of vigorous physical therapy [20]. The dorsal rhizotomy is a complex neurosurgical

procedure that produces certain risks; for example paralysis of the legs and bladder, impotence, sensory loss, wound infection and meningitis, leakage of the spinal fluid through the wound, and occasionally urinary tract infections and pneumonia. Although this method of treatment is beneficial for minimizing spasticity it is a very expensive treatment that would not be available to all patients with cerebral palsy.

Balcofen is a drug and a muscle relaxer, which treats muscle spasms caused by multiple sclerosis, cerebral palsy, or damage to the brain or spinal cord. This medicine is very effective in reducing pain and relaxing muscles, but if used for too long a withdrawal syndrome can occur, resulting in seizures and/or hallucinations [35].

Many of the procedures listed above, work to relieve pain and eventually create a means to increase muscle strength and flexibility , yet most of these procedures are expensive, risky, and have varied results and side effects associated with them. There are alternate treatments that are less precarious and are less invasive when it comes to the body.

Invasive procedures like tendon release or dorsal rhizotomy work by changing internal body tissue usually to lengthen, stretch, or redirect muscle or tendon in order to make movement easier. Alternative procedures may attempt to improve neural and motor pathways externally to produce the same or better results Some externally-focused procedures involve motor practice and the repetition of cyclic motions to establish, develop, reinforce, and improve the neural and motor pathways. Such therapies may be administered through manual assistance of a therapist or through

assistance with various mechanical devices such as exercise machines, treadmills, robots, or even live animals.

Equine-assisted therapy

Figure 3. Child receiving Hippotherapy [13]

Equine-assisted therapy (EAT) is a physical and occupational therapy treatment strategy that utilizes equine movement as part of an integrated intervention program to achieve functional outcomes. There is encouraging evidence that EAT is possibly an effective form of therapy because equine movement provides multidimensional movement, which is variable, rhythmic and repetitive [15, 16, 24, 26]. Therapy for neuromuscular disorders, as stated above, seeks to improve gait, balance, tremor, flexibility, grip strength or motor coordination. Most children with neuromuscular disorders have problems with posture, gait, joint and movement problems [24]. EAT helps to increase

trunk strength and control, balance, building overall postural strength and endurance [24, 26]. While riding a horse the patient must perform subtle adjustments in the trunk to maintain a stable position during gait transitions. The gait of a horse (walking and trotting) has many similarities to human gait, so equine movement may facilitate the neurophysiologic systems that support functional daily living skills. There is growing, quantitative evidence in the literature supporting the benefits of EAT for improving strength, flexibility, symmetry, balance, postural control, motor planning, and other abilities [15,24,26]. This would be very beneficial to patients who do not have voluntary control of their muscles, because the horse creates the movement for them. The patient is moved by the horse and responds to the horse's movement [16]. As the motion of the horse is translated to the patient, he or she will subconsciously make active responses to his or her change in position in an attempt to stay balanced upon the horse. This strengthens the muscles and reduces the likelihood of aches and pains attributed to unhealthy or dead neurons.

A study was conducted by William Benda [15] with 15 children ranging from 4 years to 12 years all who were diagnosed with spastic cerebral palsy, who met the following inclusion criteria: (1) ability to sit independently with feet on the ground and no back support; (2) ability to stand and walk independently with or without an assistive device; (3) ability to cooperate with and follow verbal directions; (4) sufficient hip abduction to sit astride a barrel. [15] These children were separated into two groups, an experimental group and a control group. Seven children were randomly assigned to 8 minutes of EAT and eight children were randomly assigned to 8 minutes riding on a barrel. The objective

of the study was to prove that repetitive cyclic movement is beneficial for the muscle improvement of children with cerebral palsy. The study yielded promising data, all children who received EAT showed a noticeable improvement in muscle response while the children who sat on the barrel had little to any improvement. However, despite the promise of EAT as a useful form of therapy, there are factors that may hinder a client from utilizing this form of therapy. These factors will be addressed in the next chapter.

CHAPTER THREE

Mechanical Horse Simulators

The live horse is obviously of great importance in equine-assisted therapy (EAT) and yet it can also introduce some challenges as well. Some patients may not have access to an EAT clinic or to the funds needed to receive EAT; Horses require a lot of maintenance, time, and money which could strain a patient or their guardians financially. Weather can also hinder opportunities for receiving therapy by riding on live horses. EAT is often not done during the cold months of winter or the hot months of summer. Horses are also not without some level of potential danger. If the client is allergic to horses or if the client falls off of the horse while receiving therapy it could potentially cause the client physical harm. The level of disability in some clients is such that it may not be safe for them to ride a live horse, even with adult assistants walking alongside. And, some patients have a fear of live horses.

A mechanical horse simulator, or MHS, is a mechanical apparatus that is designed to reproduce the movement patterns of a live horse and simulate the riding experience. A MHS, depending on the design, can complement the use of live horses for EAT by providing similar movement patterns while also addressing some of the limitations in accessibility for some clients. It can be designed to benefit each client. For example it can be designed to be lower to the ground to eliminate the danger of falling, or it can be designed to mimic the gait (walk and trot) patterns of a specific horse at

different speeds. The MHS can be more portable than a live horse and can be used indoors regardless of weather. The MHS can be used inside a clinic, facility, or even in a client's home at any time.

Current Designs

There have been a few researchers and inventors who have created different mechanical horse simulators in order to meet certain design requirements and needs.

Figure 4. iGallop MHS [34]

The iGallop is a MHS that was designed for fitness. It is supposed to target the body's core muscles and improve posture through the device's vibrating action. This MHS may be effective for exercise and muscle strengthening but does not reproduce the complex, three-dimensional, six degrees of freedom movement similar to that of a live horse,

although it has been advertised as having movement like a live horse. Also the iGallop does not appear to stimulate the muscles in any of the limbs [34].

Figure 5. Panasonic Core Trainer [23]

The MHS shown in Figure 5 was built by Panasonic with the objective of building core and thigh strength while burning calories. The Panasonic core trainer was built as a tool for exercise and not for therapy. This MHS has different speeds and a capacity to help the client exercise different muscles in the thighs depending on the orientation of the client on the saddle. Since the Panasonic core trainer was not built for therapy there was not a need for it to exactly mimic the movement of a real horse. This design produces a movement pattern that includes a basic rocking forwards and backwards, with also a slight side to side rocking. The motion pattern of a live horse is more complex, and includes six degrees of freedom : translational movement: (1) up and

down (2) left to right (3) forward and backward, and rotational movement: (4) tilting forward and backward (pitch) , (5) swiveling left and right (yaw) , and (6) pivoting from side to side (roll).

An example of a MHS that goes back and forth is the Equicize**r**, a mechanical horse that is non-motorized and moves like a rocking horse when a client rides it [33]. The Equicizer has a wooden body and has a carpet covering. The head is made to look like a real horse, and the neck attaches to the body so that it pivots, this is possible because of the springs inside the body that create resistance. It has no legs, and the rider takes the reins and pushes the neck to make it move back and forth.

There are other MHS systems that were designed specifically for physical therapy, some that work using electrical propulsion and others like the MHS built at Rose-Hulman Institute of Technology (Figure 6).

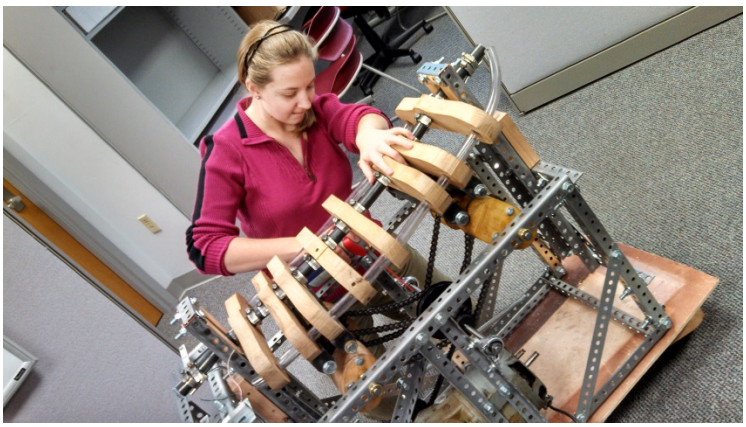


Figure 6. MHS built at Rose-Hulman Institute of Technology [27]

This MHS (Figure 6) has 6 degrees of freedom and is programmed so that an iPad can be attached; the iPad can time the session, choose between a slow, medium, or fast walk and a narrow, average, and wide horse, by utilizing padding on the MHS [27].

Studies using Mechanical Horse Simulators

A study was presented at the 2003 IEEE/ASME International Conference on Advanced Intelligent Mechatronics carried out by Youichi Shinomiya [24]. In the study riding a live horse was compared to riding a MHS with six degrees of freedom. Six markers were placed on the MHS in order to monitor the movement and compare it to the movement of a life horse. Seven riding club members and eleven riders with no experience were chosen as the subjects in the study. Each rider had a randomly selected speed (walking or trotting) to ride the MHS for 20 minutes every day for three months. 18 obese patients with type 2 diabetes (5 males and 13 females), ranging from 42 to 68 years old (average: 56.8 years) were chosen to do a study on the effects of insulin resistance. An Electromyogram (EMG) was used to measure conditions and improvement while each subject was riding the MHS. Through the signals from an EMG, or electromyogram, it was proven that long-term usage of the MHS and other developed equipment, results in an increase in the muscular strength on the extension flexion of trunk knee joint for healthy individuals and an improvement in the insulin sensitivity for obese patients with Type 2 diabetes [24]. The movement of the MHS was measured using the markers placed on the MHS and a motion capture system. The data from the motion capture system was compared to that of different horses at the two different speeds. It was proven that the movement, at both speeds, for the live horses was very similar to that of the MHS, although the walking speed produced the closest

data. This study provides encouraging evidence that the MHS could possibly be an effective complimentary tool for EAT..

Baylor MHS Device

Figure 7. Dr. Brian Garner's MHS design

Dr. Brian Garner, a professor at Baylor University, developed his own MHS design.

Dr. Garner's MHS design has six degrees of freedom and mimics the gait motion of a specific horse. This is mostly attributed to a set of irregularly-shaped cams that drive linkages and control the riding platform (saddle) motion.

Figure 8. Cams from Dr. Garner's initial design

These irregularly shaped cams were designed by recording the movement of an actual horse using motion capture software. Then a computer model was developed in order to design the set of cams to mimic the movement of the specific horse. As the motor turns these cams move the follower arms which are attached to cables that move the riding platform of the mechanical horse. This system of cams, follower arms, and cables are the mechanisms that create the six degrees of freedom movement pattern. In essence, the riding saddle platform is moved by the cables like a puppet is moved by the puppeteer. The shapes of the cams determine the movement pattern, and can be programmed to provide realistic, three-dimensional, six degree-of-freedom movements.

Each MHS is different because they are designed to meet different requirements that will satisfy their clients. But, how does one know the requirements have been met and, if they have been met, to what extent? As one example, a study using the Panasonic MHS on post-stroke patients [25] used a three scale score assigned by a therapist that observed the patient after they ride the MHS. This way of measuring

improvement seems very subjective because there are many different outside factors that could influence the therapist's ability to score the patient. Other therapists could possibly give the patient a slightly higher score or a slightly lower score.

Methods of Measuring Improvement

There is a need for objective quantitative data, to assess any improvement in each client. There are a few such methods that measure certain parameters as the client is riding or after they have ridden the MHS. The three most common ways of measuring data from a client riding an MHS are EMG, Force Plates, and Motion Capture Systems.

EMG

Figure 9. Benda example of EMG [15]

Electromyography (EMG) is a technique for evaluating and recording the electrical activity produced by skeletal muscles. EMG is performed using an instrument called an electromyograph, to produce a record called an electromyogram. An electromyograph detects the electrical potential generated by muscle cells when these cells are electrically or neurologically activated. The signals can be analyzed to detect medical abnormalities, activation level, or recruitment order or to analyze the biomechanics of human or animal movement [25]. Analyzing data from an EMG can be difficult because recordings of electrical activity of muscles can be contaminated by interference from the electrical supply, mechanical artifacts, and activity of other muscles. Therefore it may be difficult, when analyzing data, to distinguish between the data signal and the

error that may occur while collecting the data. This makes it hard to come to a conclusion of whether the client's needs were met.

Force Plates

Figure 10. Subject jumping on force plates [30]

Force platforms or force plates are measuring instruments that measure the ground reaction forces generated by a body standing on or moving across them, to quantify balance, gait and other parameters of biomechanics. Some force plates are portable and measure the average location of the center of pressure (CoP). There are two types of force plates, Piezoelectric and Strain Gage. Piezoelectric force plates do not need a power supply because of the transducers that produce an electric charge when they are stressed. Strain Gauge force plates use strain gauges to measure stress and require excitation of the strain gauge bridge circuit [29]. Force plates are mostly used to analyze posture improvements, but can be very expensive and are not widely available in most clinical settings [28].

Motion Capture Systems

Figure 11: (left) motion capture system at Baylor University (right) marker suit motion capture [31]

Motion capture is the process of recording the movement of objects or people and translating it into digital data, usually using some form of markers or indicators.

With some systems an array of video cameras are connected to a computer running specialized software [31], others utilize simple video recording cameras and then the video from the cameras is uploaded to a computer were the video is converted into data. In most motion capture systems, markers are used in order to collect data (Figure 11 right). These markers are designed to be easily identifiable by image processing software. Typically, the markers are either highly reflective balls or small LEDs that stand out from the background and are simpler for computer vision algorithms to identify [31]. Motion capture can be a very effective way of measuring a client's trunk posture but the motion capture process can be long and tedious. Thoughtful and careful

positioning of the markers on a subject is essential, as the software uses these to track the position of the subject. If the markers are misapplied, or become blocked by another object [32], the tracking will be inaccurate, and the data will be unusable.

In conclusion, past studies suggest that the MHS systems may be an effective option for therapy for people with neuromuscular and neurological disorders and diseases, and one promising method of measuring improvement is through a motion capture system.

CHAPTER FOUR

Methods

Experiments were designed to use a motion capture system to assess any improvements in clients postural stability following time riding on the Baylor MHS at an EAT clinic near Waco, Texas, An experimental setup was created in order to have organized data collecting sessions at the clinic. In addition to the motion capture data, subjective feedback from the client was collected over questions such as: What do you like about the MHS? What would you prefer be different or better? How does the MHS affect client motivation for therapy? All experiments and questionnaires were approved by the Baylor IRB, and participants signed informed consent.

The MHS designed at Baylor University was installed at the local, licensed therapy clinic. Here data was recorded on a normal subject (control) and then on a client with a severe case of spina bifida who is paralyzed from the waist down. The client, who had missed previous EAT sessions, expressed her enjoyment when riding the Baylor MHS. She mostly enjoyed the fact that the MHS was a lot closer to the ground than the live horses she would ride during EAT, and she expressed an interest to continue riding the MHS for her therapy sessions. The only complaint the client had was that she had nothing to look at as she was riding the MHS.

The objective measures were recorded of client capabilities to see if use of the MHS had any effect on these capabilities. The objective measures were derived from

video recordings of the client's movement patterns for the purpose of tracking posture of the hips, spine, and head. Two standard video cameras were set up to record the back view and side view, operating independently to give two different planar views. To facilitate tracking of the body segments, several small LED markers were placed on a motion capture jacket using hook-and-loop attachments to keep the markers positioned in the proper place. The motion capture jacket is made out of polyester stretchy fabric so that clients with many different body types could wear the jacket while riding the MHS. LED markers were placed on the helmet of both the control and the client, on the neck (cervical vertebrae) of the jacket, the mid back (thoracic vertebrae T7), and the lower back (lumbar vertebrae). Along with the LED jacket both subjects wore a pelvis belt which includes LED markers on the left and right side of the belt (see Figure 12). The client was recorded 30 seconds before riding on the MHS sitting as still as they could while the MHS was turned off. Then the MHS was turned on and the client was recorded for the first 120 seconds of riding. The cameras were then turned off while the client then rode on the MHS for 30 minutes. Near the end of the same riding session, in the last 120 seconds of the ride the client and control were also recorded again with the cameras. After the riding session was over the MHS was turned off and the client and control were recorded for 30 seconds again sitting up and still. The control rode the MHS for 6 minutes continuously instead of the regular 30 minute session. Using SimiMotion software with the motion capture system, the videos from the motion capture system were uploaded, the markers were tracked and the angles of line segments between the head and neck (HA), neck and mid back (UB), mid back and lower

back (LB), and from left hip to right hip (PB) were developed and exported as a txt file. The angles of line segments HA and UB were noted with respect to the vertical, while that of line segment PB were note with respect to the horizontal. The data was then loaded into Matlab and graphed to show angle versus time.

Figure 12 Example of Marker Tracking and lines between markers using SimiMotion Software

CHAPTER FIVE

Results and Discussion

The results include neck, upper-back, and pelvis angles recorded over time while sitting still and while riding the mechanical horse simulator(MHS). The subjects include a healthy “control” subject and a “client” that is paralyzed from the waist down due to spina bifida. Although two cameras were utilized for data collection, only data from the back-view camera could be processed.

Due to the large physical size of the client, the markers for the side-view camera became obscured at times and thus could not be used. The body segment angles recorded by the back-view camera for trials including

The first 30 seconds stationary before riding, the first 120 seconds while riding, the last 120 seconds while riding , and the last 30 seconds stationary after riding.

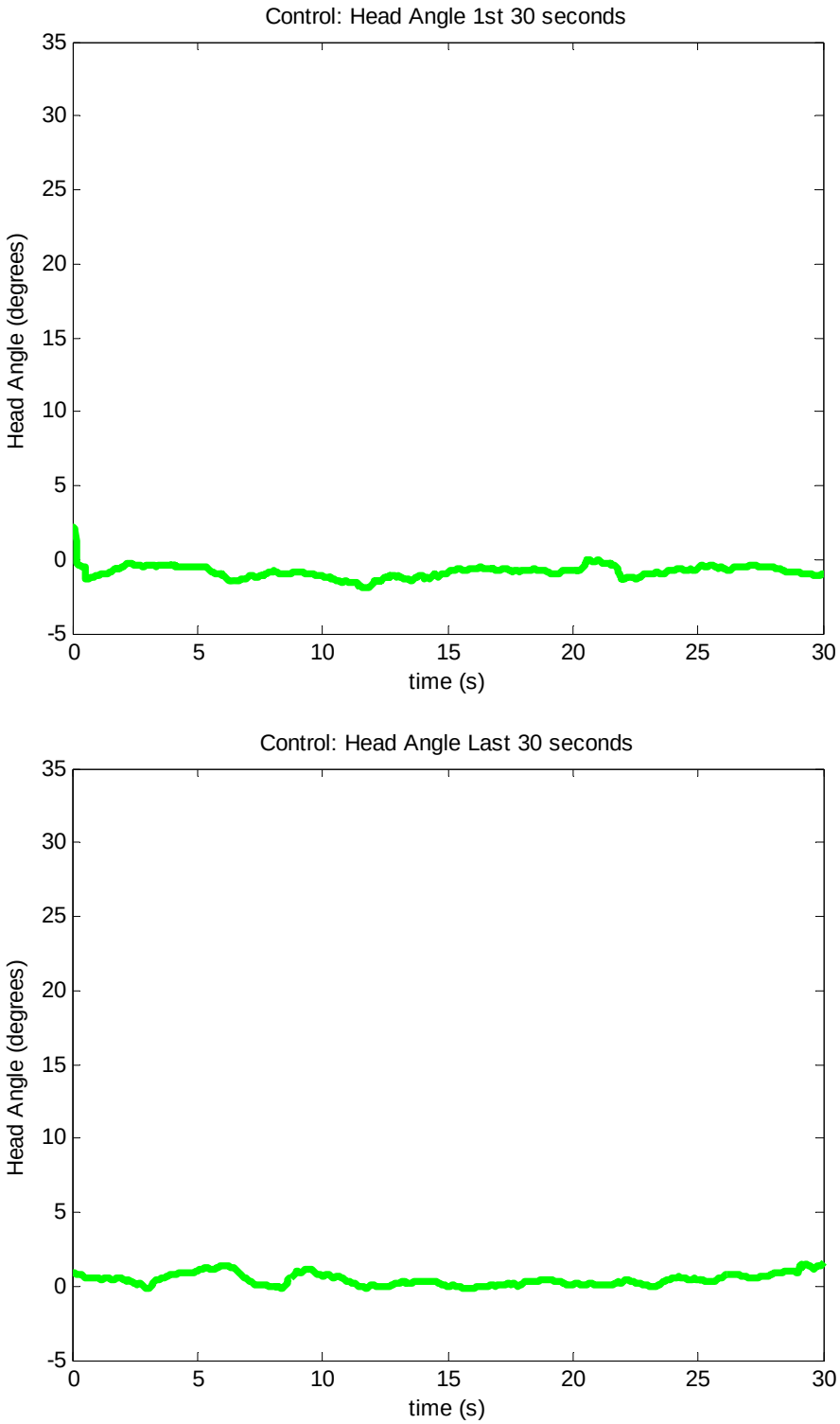


Figure 13 Control HA Graphs (top) 30 sec stationary before riding (bottom) 30 sec stationary after riding

Figure 13 shows the magnitude angle of the line segment between head and neck marker with respect to vertical for the control 30 seconds stationary before and after riding the MHS. Analyzing the dependent axis or the angle axis, if there's a large range from the largest angle to the smallest angle, or the delta angle, this means that the subject does not have as much control over their head and neck. In order for the subject to exhibit improvement with any of the angles previously described, the delta angle must decrease or in other words the graph must become more stable. Comparing the graph of the first 30 seconds and the last 30 seconds it is seen that in both cases the head angle remains fairly constant with a range of about 2 degrees. This consistency is expected from the control subject who did not necessarily need to improve because they are already healthy.

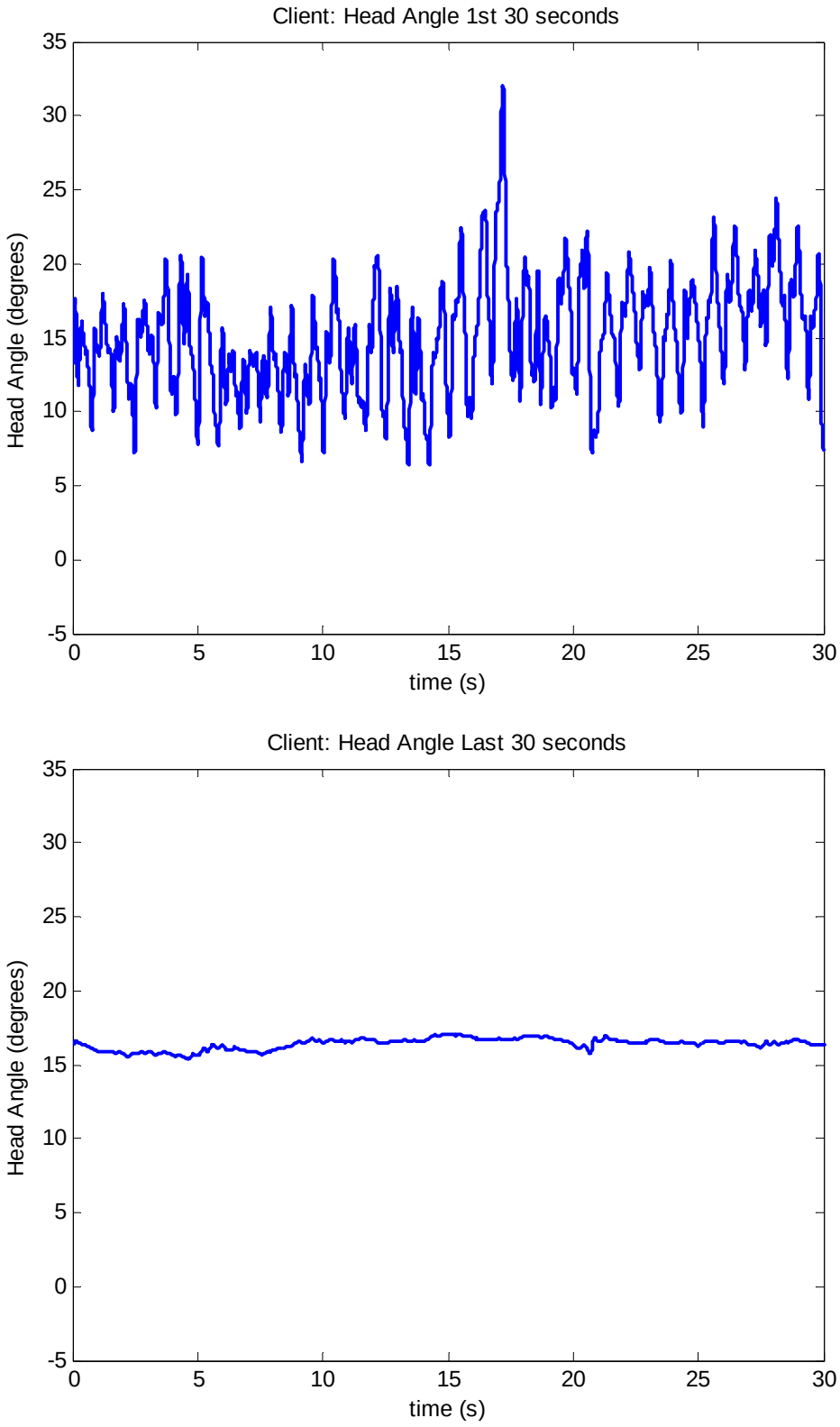
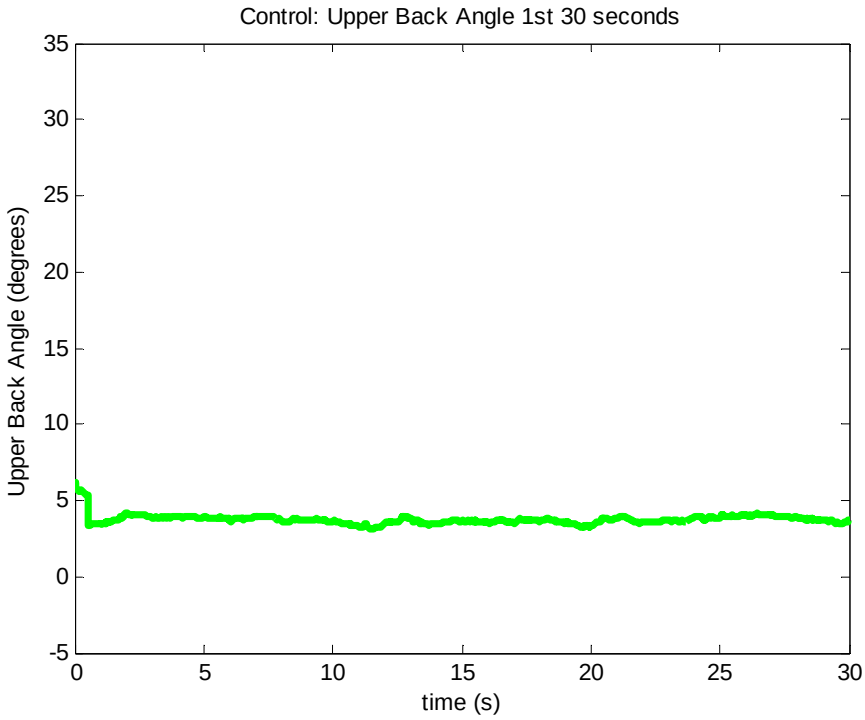
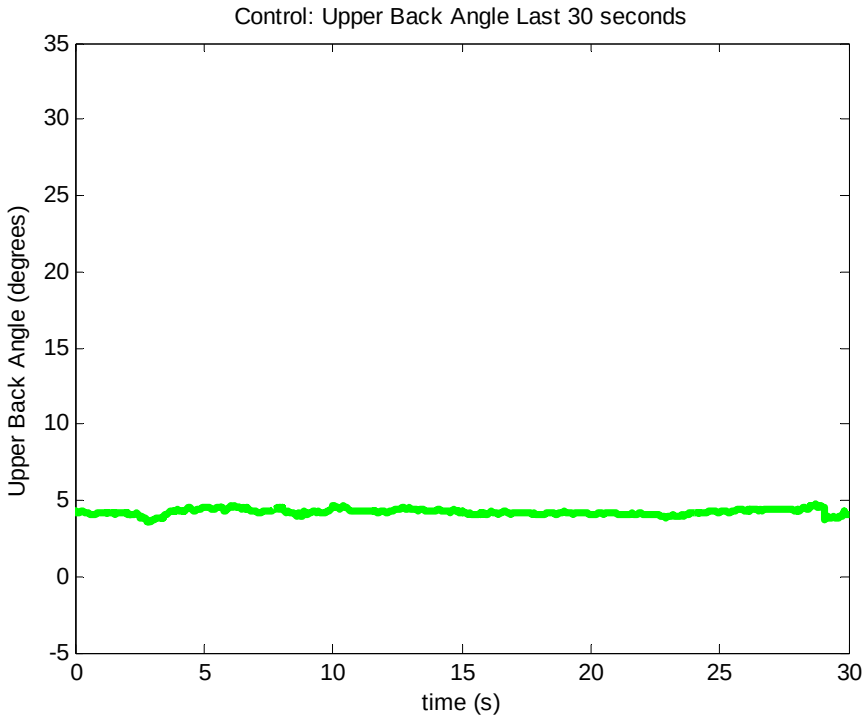


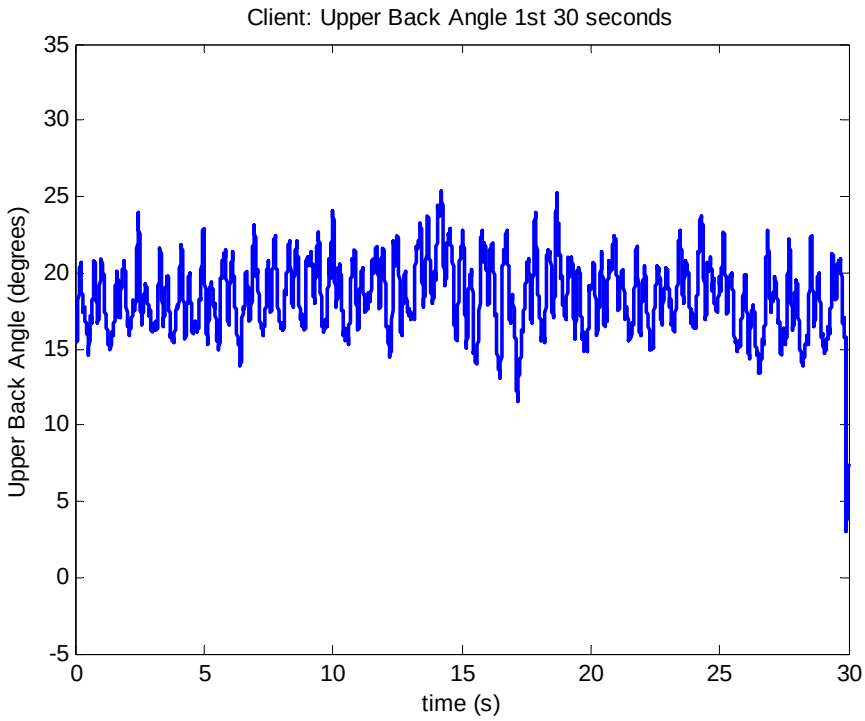
Figure 14 Client Head Angle Graphs (left) 30 sec stationary before riding (right) 30 sec stationary after riding

Figure 14 shows the magnitude angle of the line segment between head and neck marker with respect to vertical for the client with severe spina bifida 30 seconds stationary before and 30 seconds stationary after riding the MHS. The client exhibited a much higher change in delta angle from the first 30 seconds to the last 30 seconds while the horse was stationary. Before riding the stationary head angle was unstable and varied by as much as 27 degrees with oscillations that occurred faster than once per second. After riding the stationary head angle was much more stable and varied by less than 1 degree. Nevertheless, there remained a stationary head tilt (offset angle) of about 16 degrees both before and after riding.

Upper Back angle Graphs







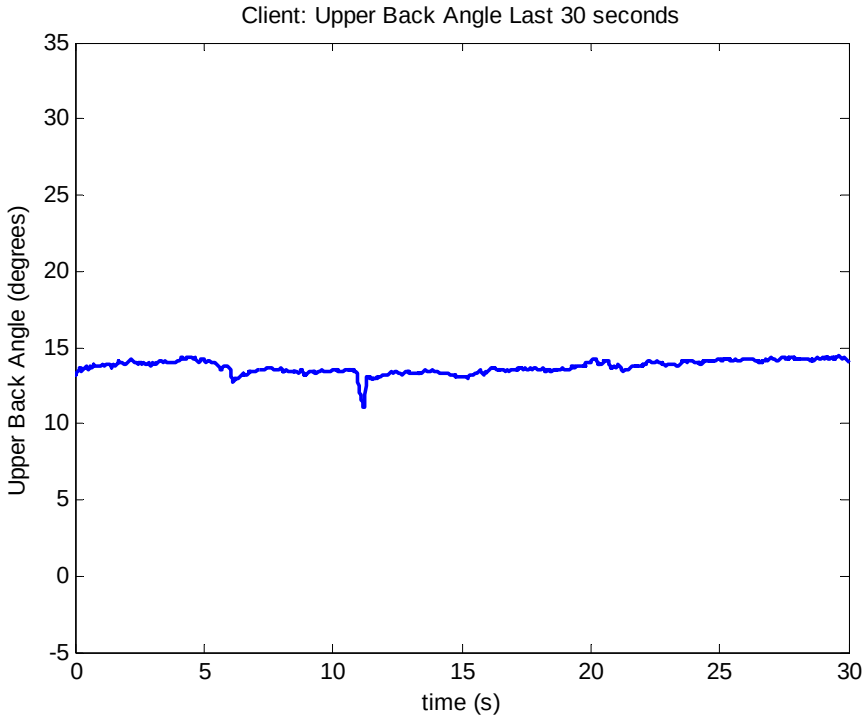


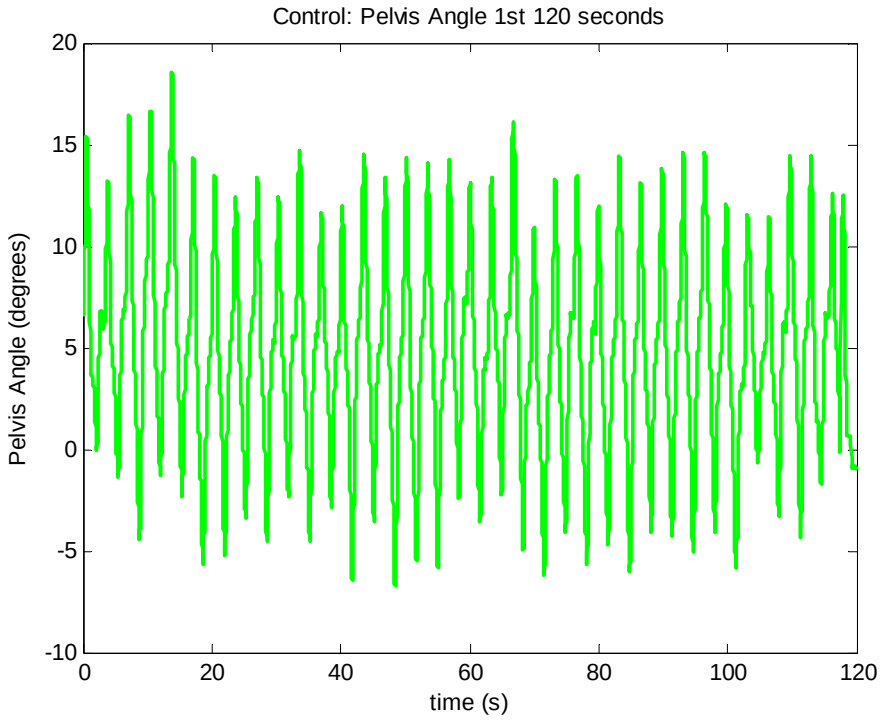
Figure 15 Control (previous page) and Client (current page) Upper Back Angle Graphs for first 30 seconds before riding (upper graphs) and last 30 seconds after riding (lower graphs) with MHS stationary.

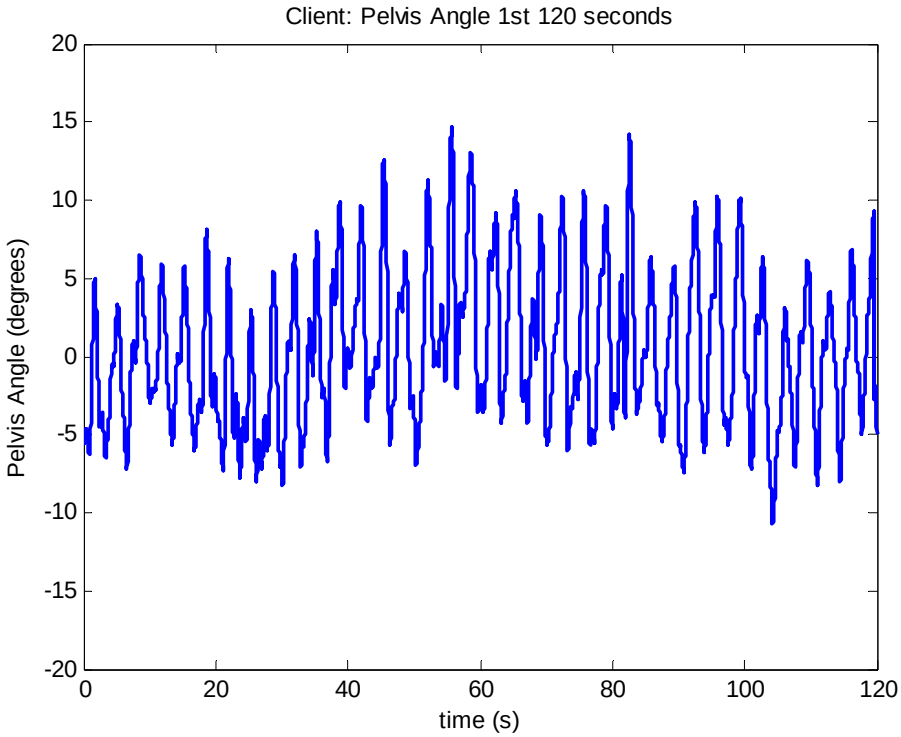
Figure 15 shows the magnitude angle of the line segment between neck and back marker with respect to vertical for the control subject and client during 30 seconds stationary before riding and 30 seconds stationary after riding the MHS. As with neck angle, the back angle remained quite stable for the control subject both before and after riding. However for the control subject the back angle range decreased about 75% of the original value. The client decreased the delta angle from 12 degrees to 3.3 degrees. From the values of the delta angles displayed in Table 1 it is shown that for stationary posture of the head , upper back, lower back, and pelvis angles, the control subject remained fairly stable, while the client subject tended to improve stability by way of decreased angle range.

	Delta Angles for Control and Client 30 Seconds Before and After Riding the MHS			
	Client 1st 30 sec (deg)	Client Last 30 sec (deg)	Control 1st 30 sec (deg)	Control Last 30 sec (deg)
Head	27	0.8	2	1.8
Upper Back	14	3.5	2.6	1.2
Lower Back	16	1.3	3.2	3.8
Pelvis	25	2.1	1.9	23

Table 1. Delta Angles for Client and Control for 1st and last 30 seconds stationary

Pelvis Graphs





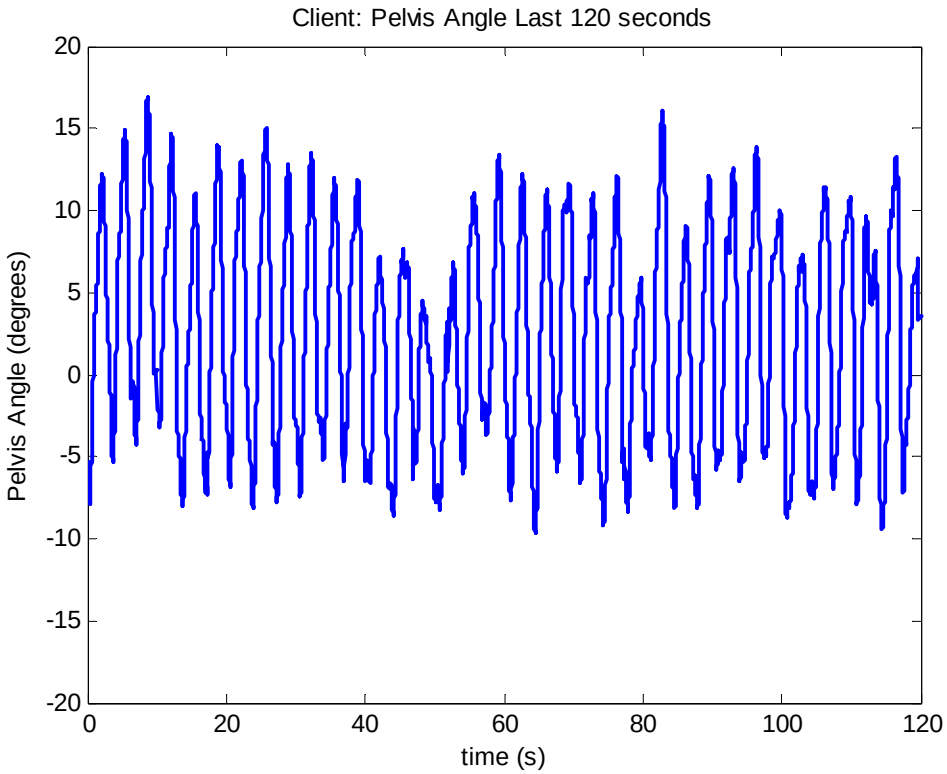


Figure 16. Comparison of Control subject (previous page) and Client subject (current page) for Pelvis angle with respect to horizontal for the first 120 sec of riding and the last 120 sec after riding (Client only; lower graph this page).

Figure 16 shows data that was recorded as the control rode for the first 120 seconds of their six minute riding session and as the client rode for the first and last 120 seconds of their 30 minute riding session. The MHS was moving while the data was collected so it is expected that the pelvis angles will oscillate. The control's data is more uniform, stable, and has the look of a sinusoid with similar amplitudes and a steady wavelength. The client's graph for the first 120 seconds of riding is not very uniform and the amplitudes have almost no correlation as seen in Table 2. The client's graph for the last 120 seconds shows a more consistent pattern, with a more steady amplitude and wavelength. For the client the before-after differences in the pelvis angle amplitudes decreased for the head, lower back, and for the pelvis, suggesting there was

improvement in stability in these areas. This type of improvement was, not observed for the upper back.

	Amplitude for Control and Clients 120 Second Trials While Riding the MHS				
	Client 1st 120 sec (deg)	Biggest Difference	Client Last 120 sec (deg)	Biggest Difference	Control 120 sec (deg)
	t= 20 60 100 (sec)		t= 20 60 100 (sec)		t= 20 60 100 (sec)
Head	6.25 5 9.5	4.5	4 3 5.5	2.5	5 5.5 7.75
Upper Back	3.5 4 3	1	1.9 1.7 2.9	1.2	0.85 4 3.95
Lower Back	5 3.5 1.5	3.5	2.5 3.6 5.4	2.9	5.5 6.75 1
pevis	2 8.5 8.5	6.5	10.25 10.25 9.25	1	9 8 9

Table 2. Amplitudes for Client and Control for 1st and last 120 seconds at 20 sec, 60 sec, and 100 sec

Significance

The purpose of this thesis research was to establish a method and perform a pilot case study to quantitatively assess improvements in trunk posture and stability from riding on the MHS. The method permitted measurement of trunk segment angles during stationary trials and movement trials, both before and after a period of riding on the MHS. The pilot case study showed quantitatively from the segment angle ranges that after a 30 minute session of riding a client with severe spina bifida could exhibit improvement in trunk posture and stability. Each set of angles (Head, Upper Back, Lower Back, and Pelvis) exhibited improvement in range (Table 1), for the 30 seconds stationary before and after riding the MHS. The healthy control exhibited good stability and posture both before and after riding. Another stability measure was assessed using the amplitude of the 120 second movement trials. From Table 2 the client showed improvement in stability with the Head, Neck, Pelvis, and lower back. The results provide encouraging quantitative data that shows that the MHS may help improve trunk posture and stability in subjects with neuromuscular disabilities.

Possible Error

As stated before and shown in this study, motion capture has the potential to be a very effective way of measuring a client's trunk posture but the motion capture jacket did present some difficulties in collecting data. Due to the large physique of the client the markers were not in their specified places and had to be moved after the client wore the motion capture jacket, this contributed to a longer wait time for the client as the markers were repositioned. Precise application of the markers is essential, as the software is estimating the position of the subject. The markers at one point became blocked by the client's hair and there was an outside light interference that caused the SimiMotion software to stop tracking automatically. This affected the shoulder data which eventually could not be used (Figure 16).

Figure 17. Example of error contributed from outside light

Data was taken from a side camera but unfortunately some of the markers positioned for that camera were obscured, so tracking for the side camera proved unusable.

Future Research

Though encouraging, the data from this current study represents only a single Control subject, and single Client subject, for a single set of trials. Future research should focus on a large subject pool with varied forms of disability, improved positioning of the side camera and side markers, more in-depth analysis of the body segment angle data patterns, and more long-term study over multiple weeks of treatment. The MHS design may benefit many clients with neuromuscular and neurological disorders in other clinics around Texas and the nation.

APPENDIX

Motion Graphs

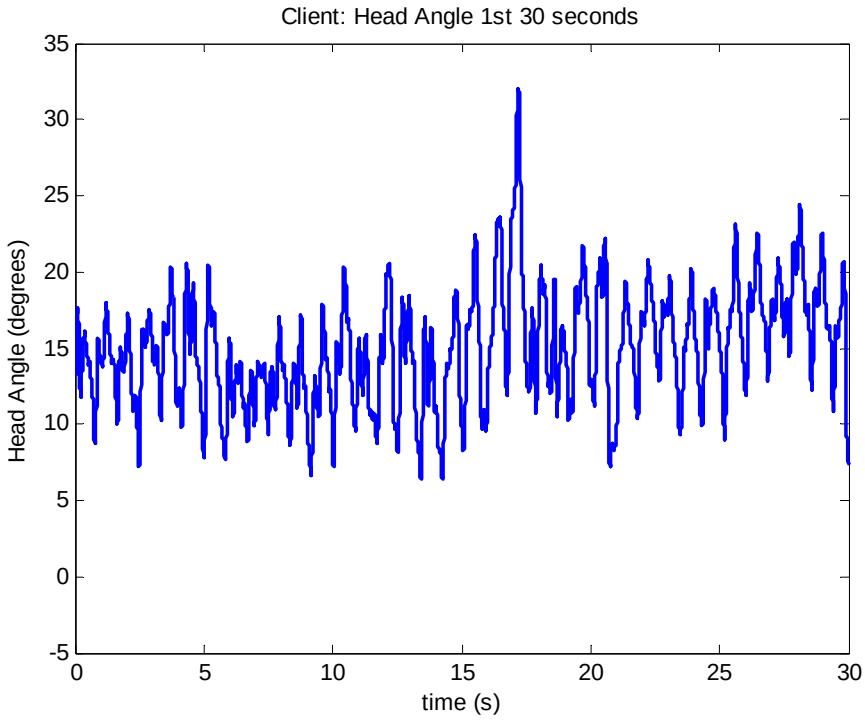


Figure A1. Client Back Camera Head Angle 1st 30 second trial stationary

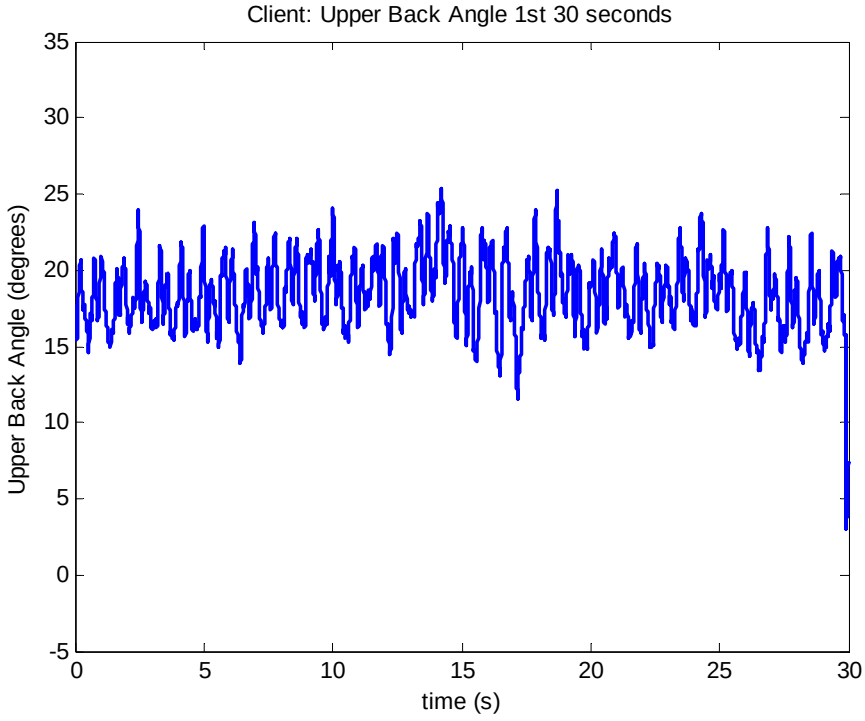


Figure A2. Client Back Camera Upper Back Angle 1st 30 second trial stationary

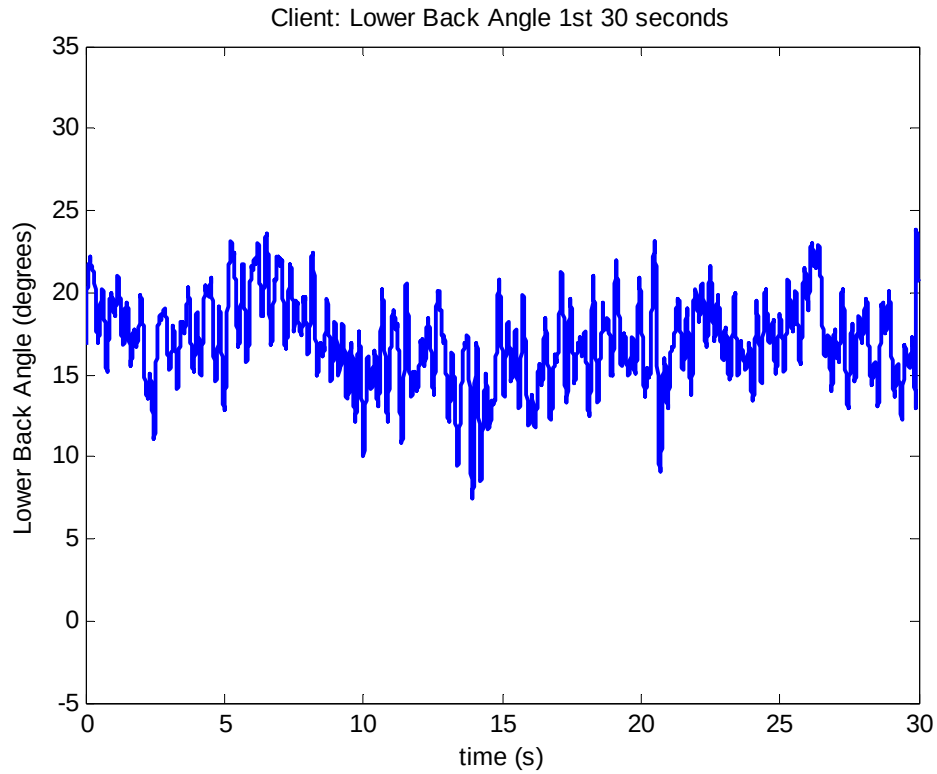


Figure A3.Client Back Camera Lower Back Angle 1st 30 second trial stationary

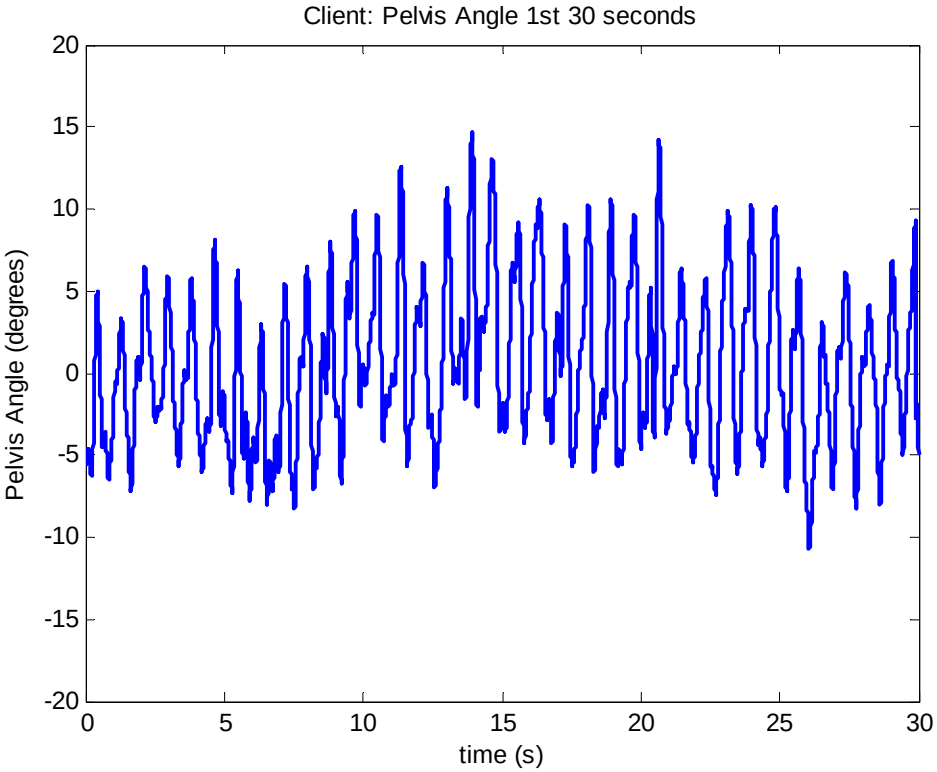


Figure A4.Client Back Camera Pelvis Angle 1st 30 second trial stationary

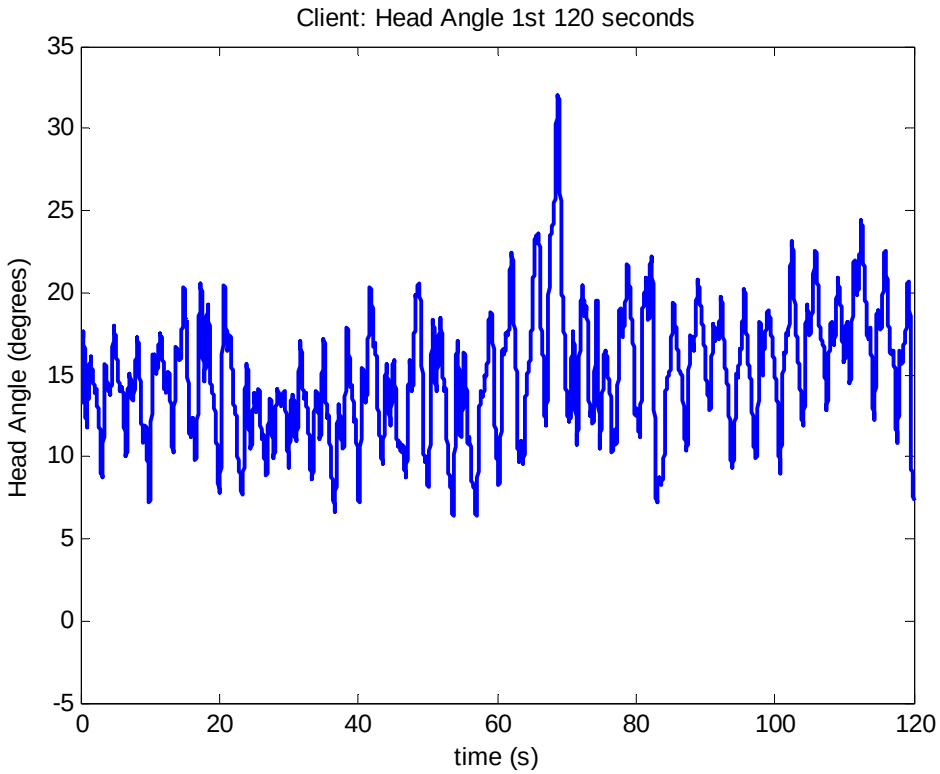


Figure A5. Client Back Camera Head Angle 1st 120 seconds

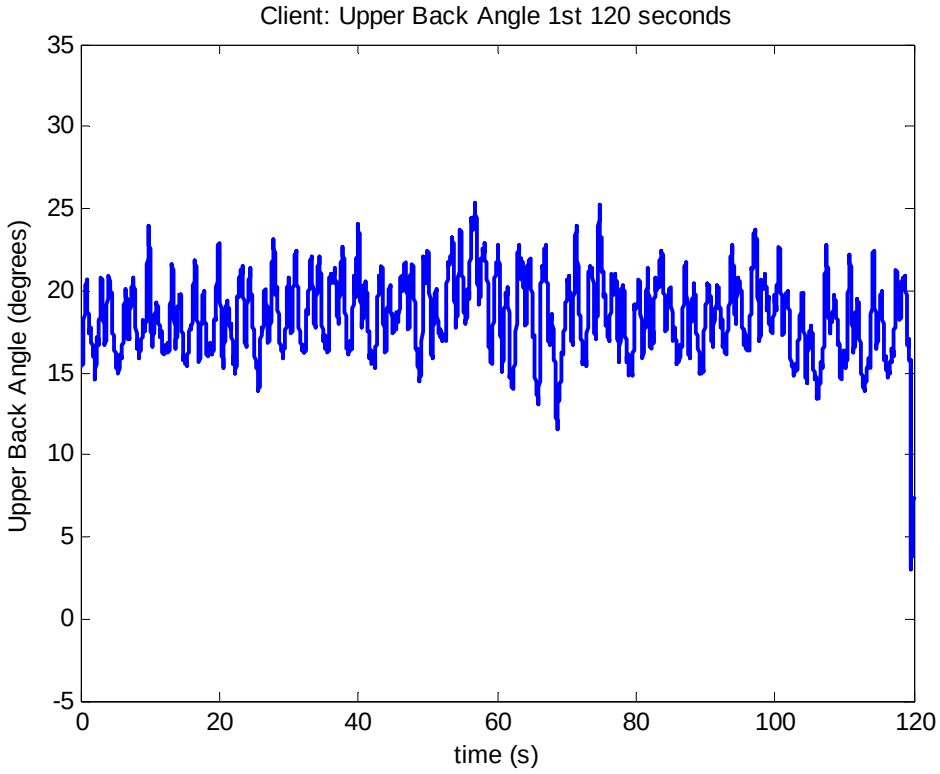


Figure A6. Client Back Camera Upper Back Angle 1st 120 seconds

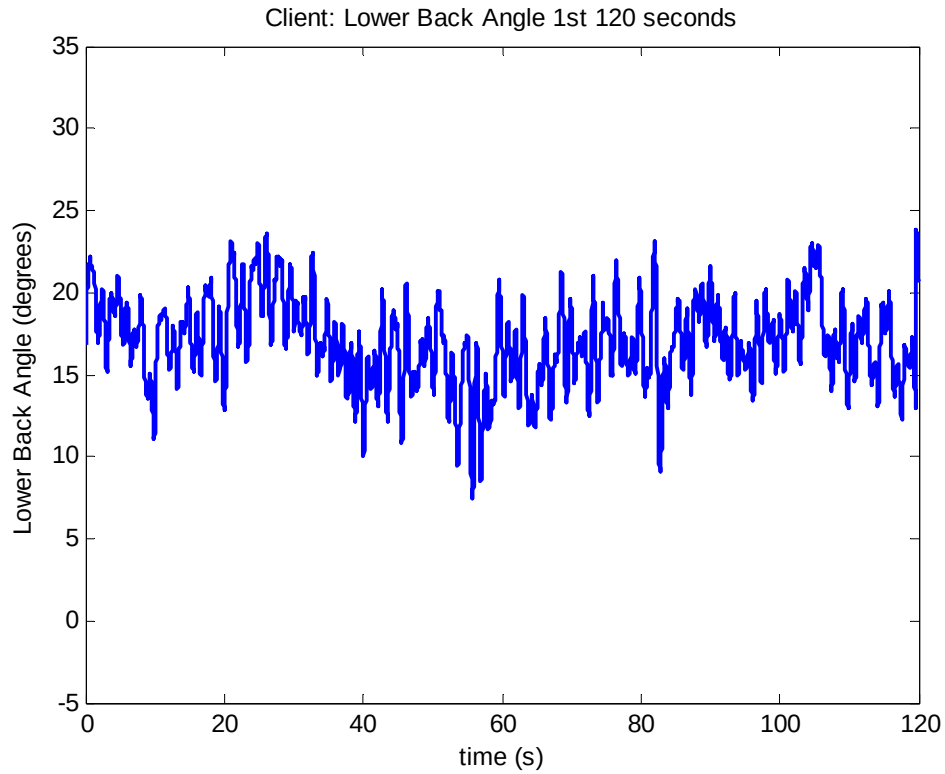


Figure A7. Client Back Camera Lower Back Angle 1st 120 seconds

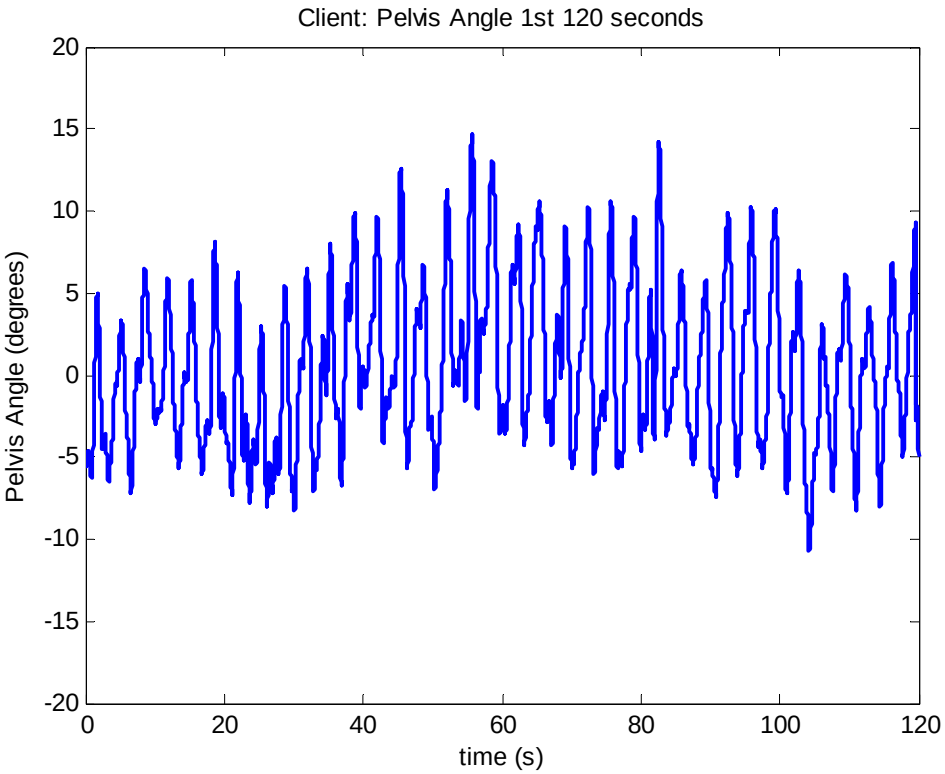


Figure A8. Client Back Camera Pelvis Angle 1st 120 seconds

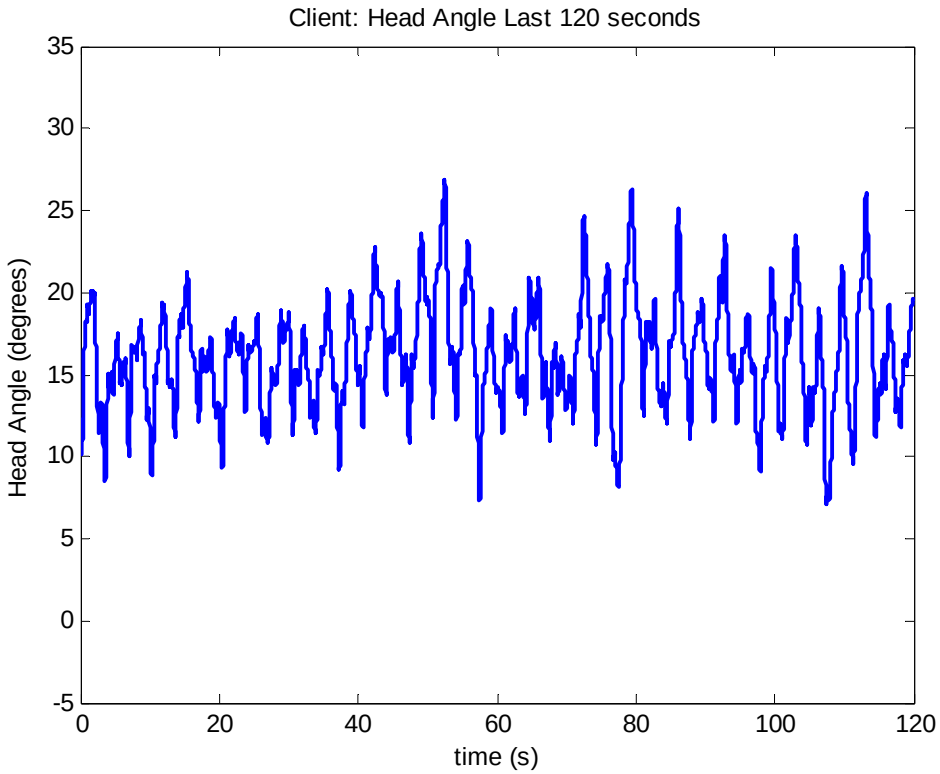


Figure A9. Client Back Camera Head Angle Last 120 seconds

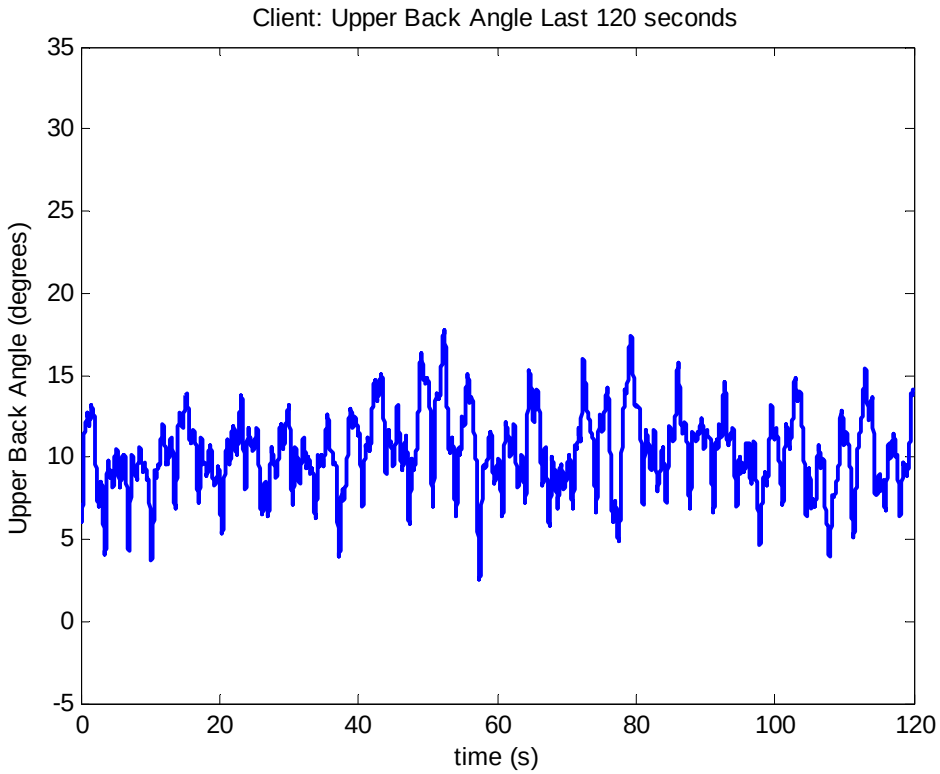


Figure A10. Client Back Camera Upper Back Angle Last 120 seconds

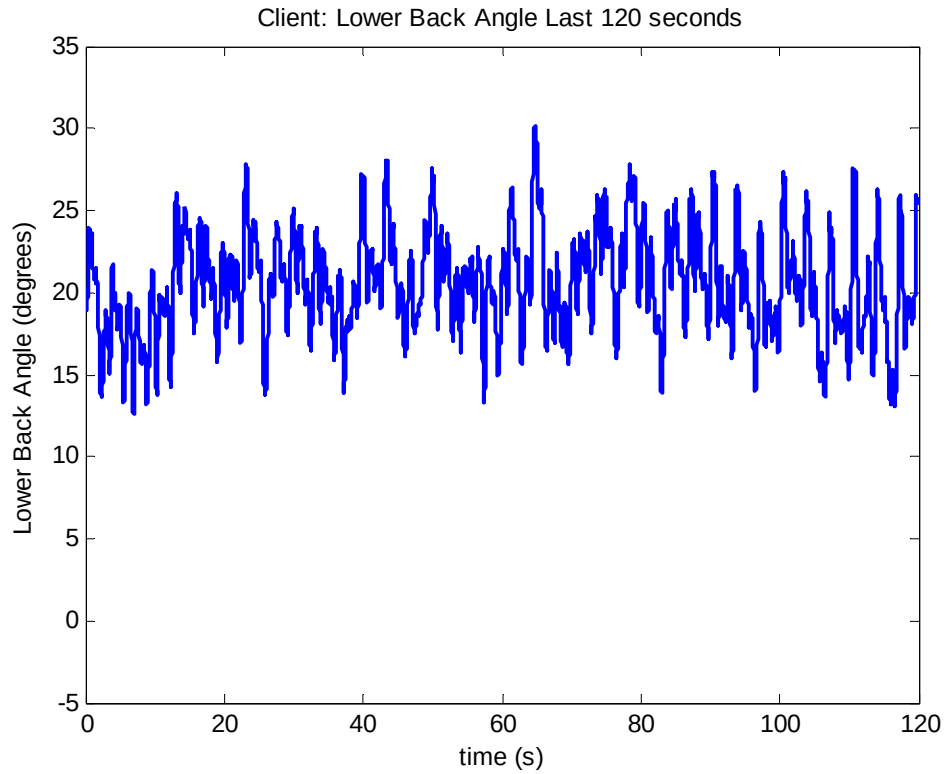


Figure A11. Client Back Camera Lower Back Angle Last 120 seconds

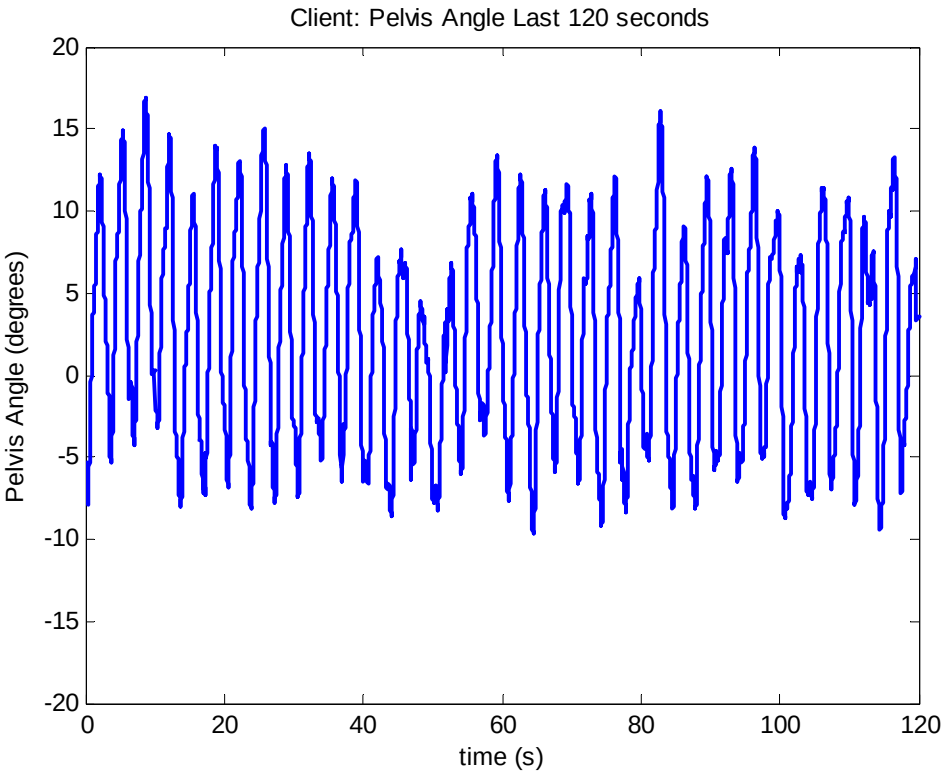


Figure A12. Client Back Camera Pelvis Angle Last 120 seconds

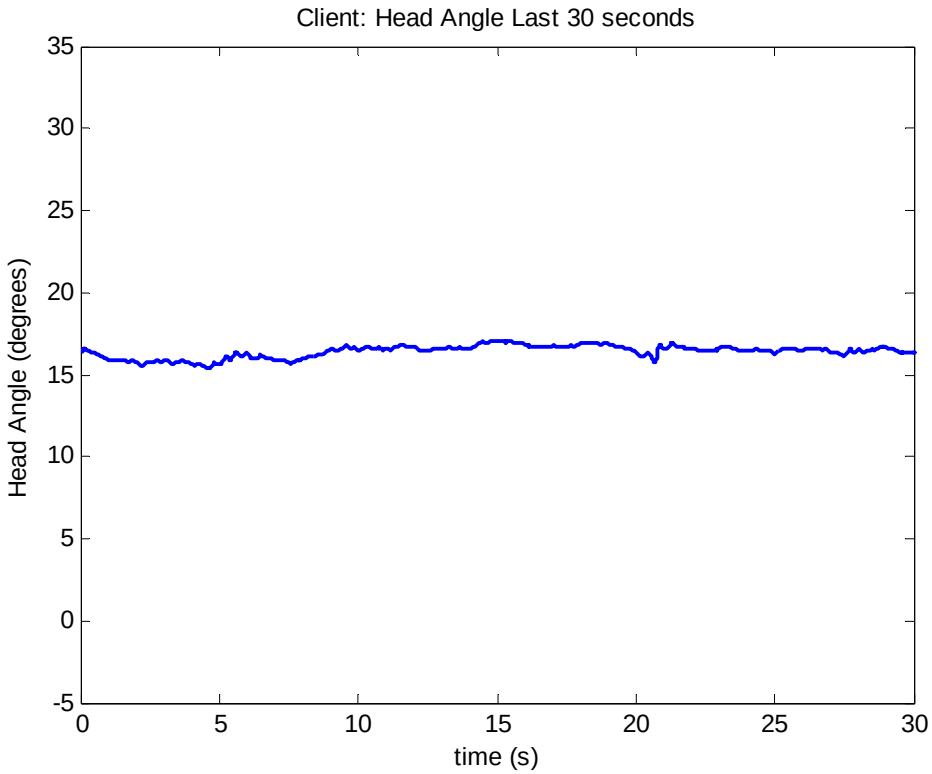


Figure A13. Client Back Camera Head Angle Last 30 seconds stationary

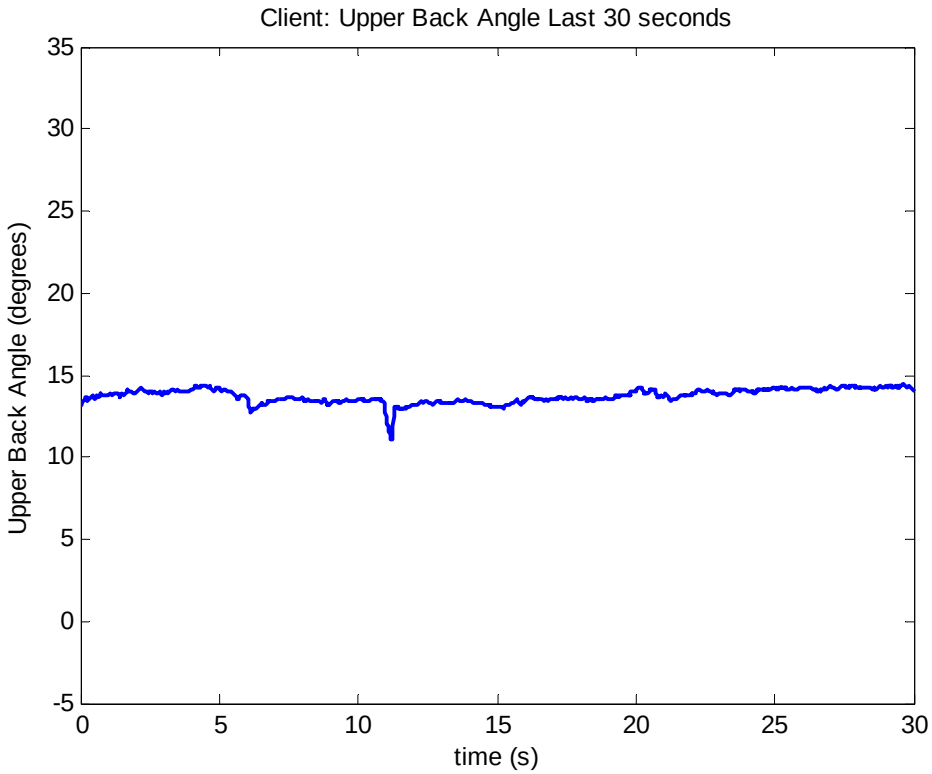


Figure A14. Client Back Camera Upper Back Angle Last 30 seconds stationary

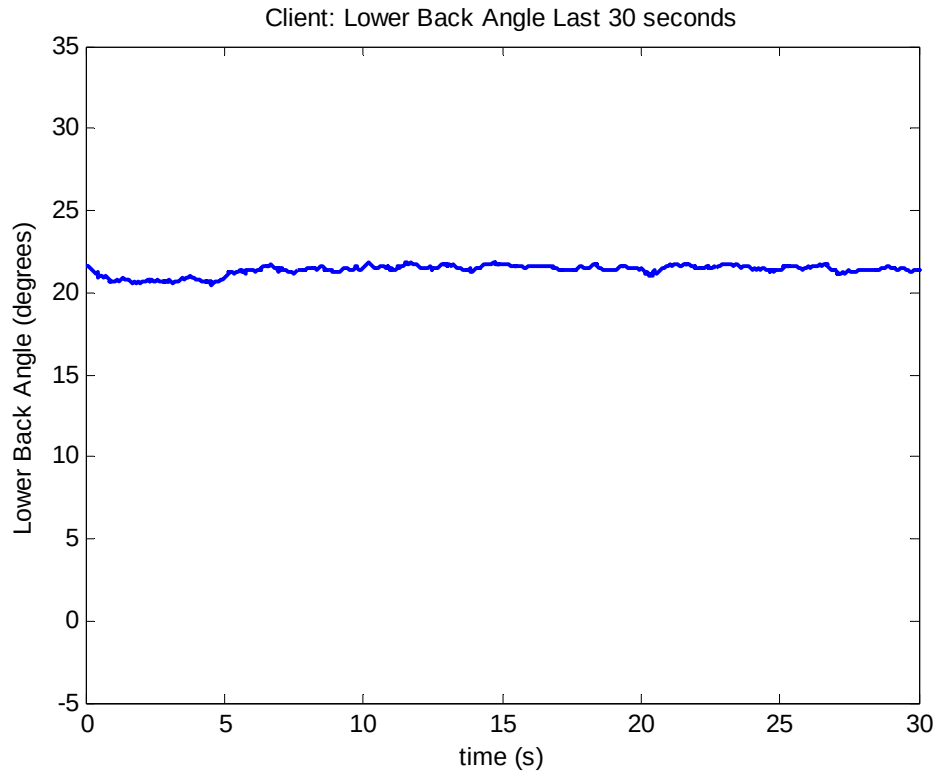


Figure A15. Client Back Camera Lower Back Angle Last 30 seconds stationary

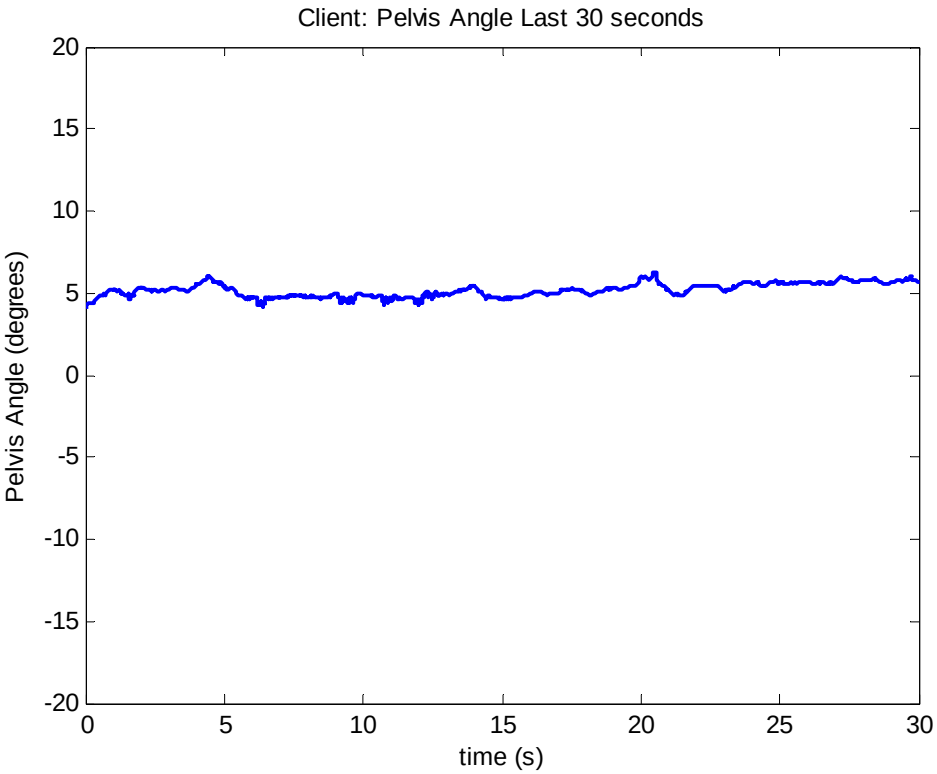


Figure A16. Client Back Camera Pelvis Angle Last 30 seconds stationary

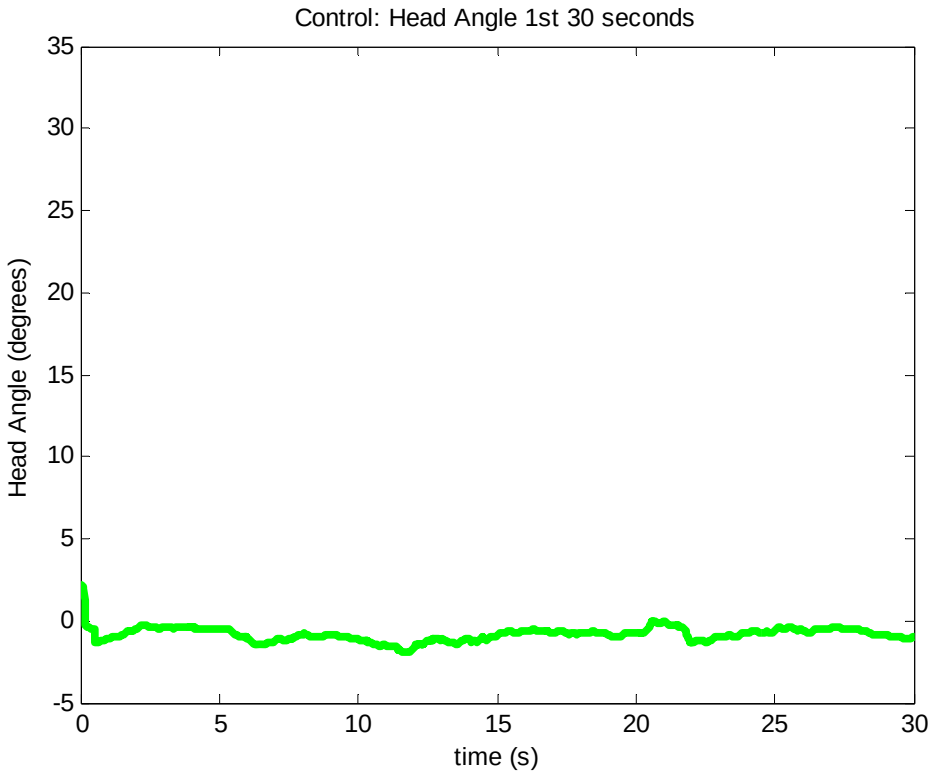


Figure A17. Control Back Camera Head Angle 1st 30 seconds stationary

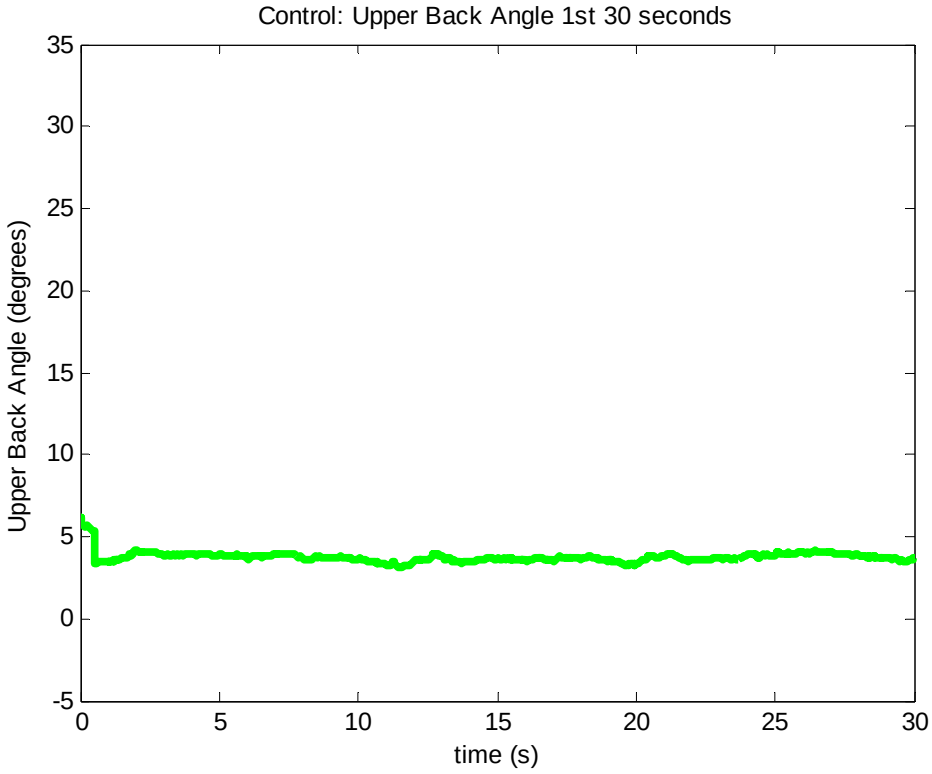


Figure A18. Control Back Camera Upper Back Angle 1st 30 seconds stationary

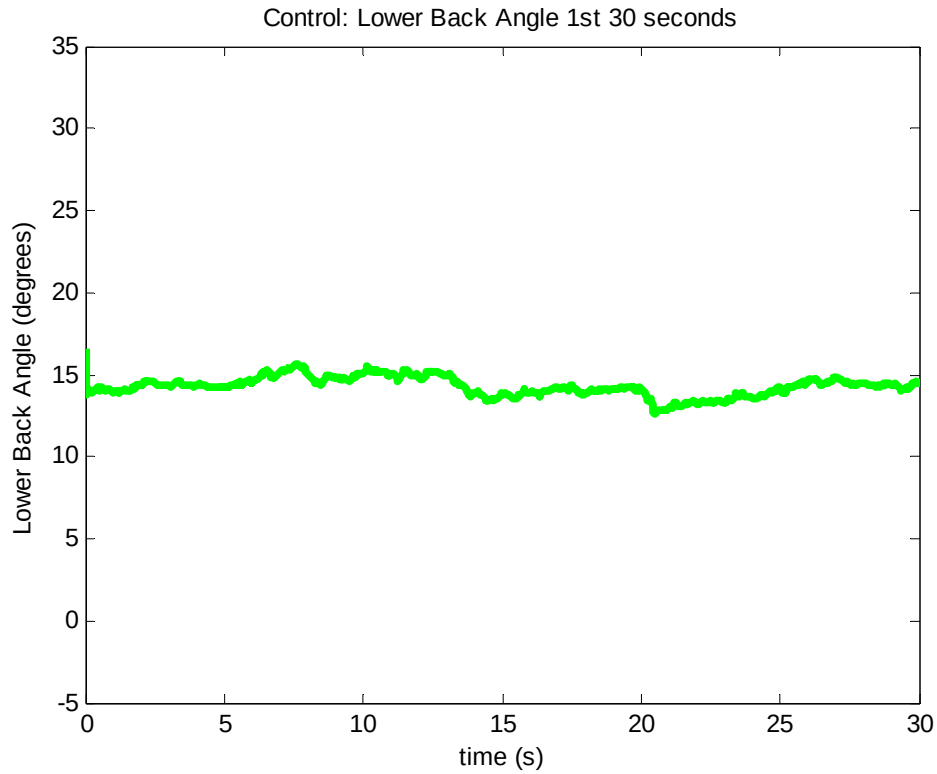


Figure A19. Control Back Camera Lower Back Angle 1st 30 seconds stationary

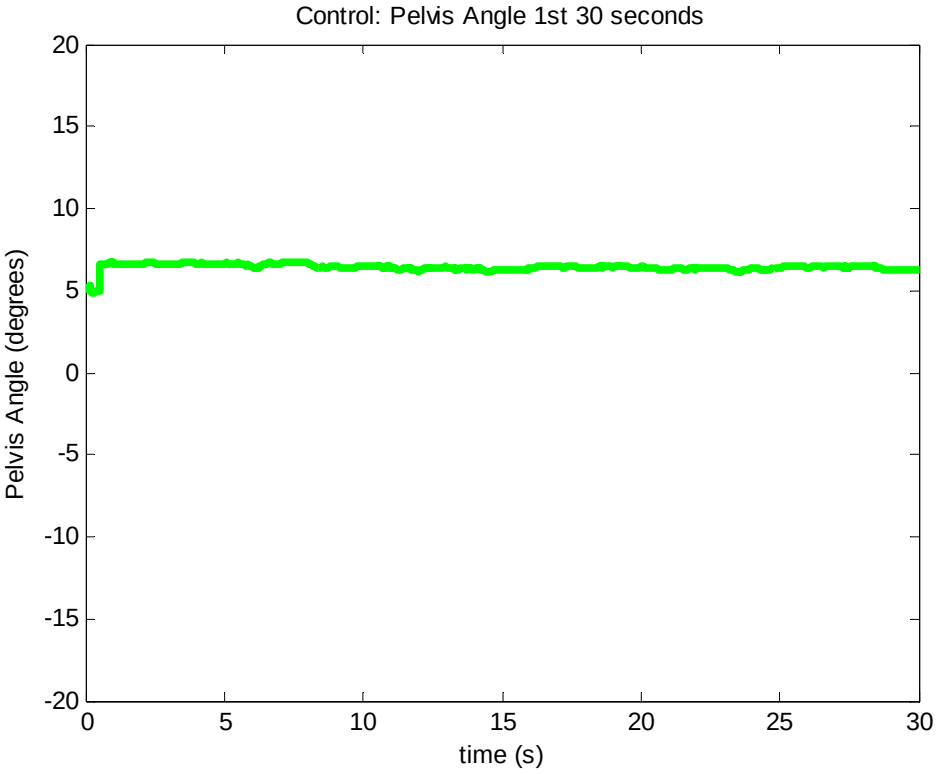


Figure A20. Control Back Camera Pelvis Angle 1st 30 seconds stationary

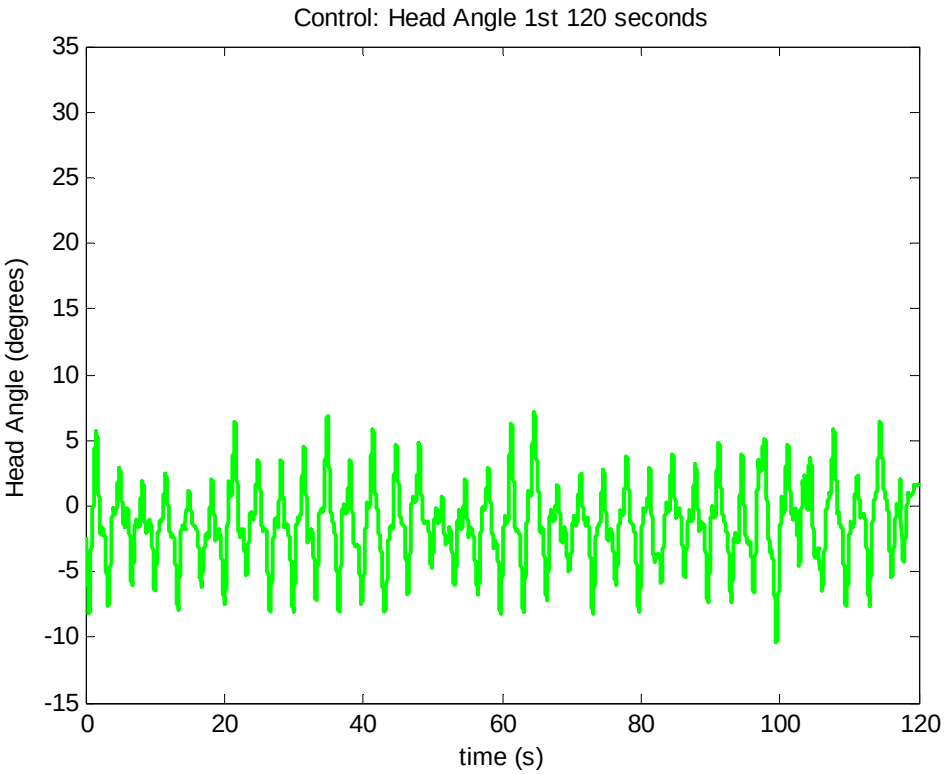


Figure A21. Control Back Camera Head Angle 1st 120 seconds

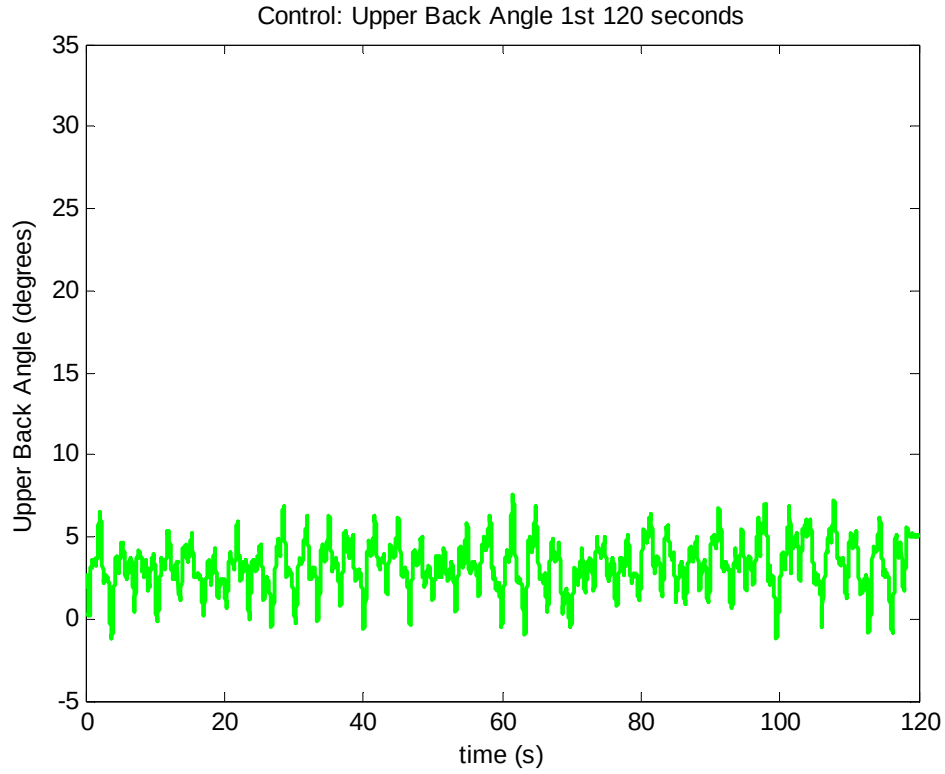


Figure A22. Control Back Camera Upper Back Angle 1st 120 seconds

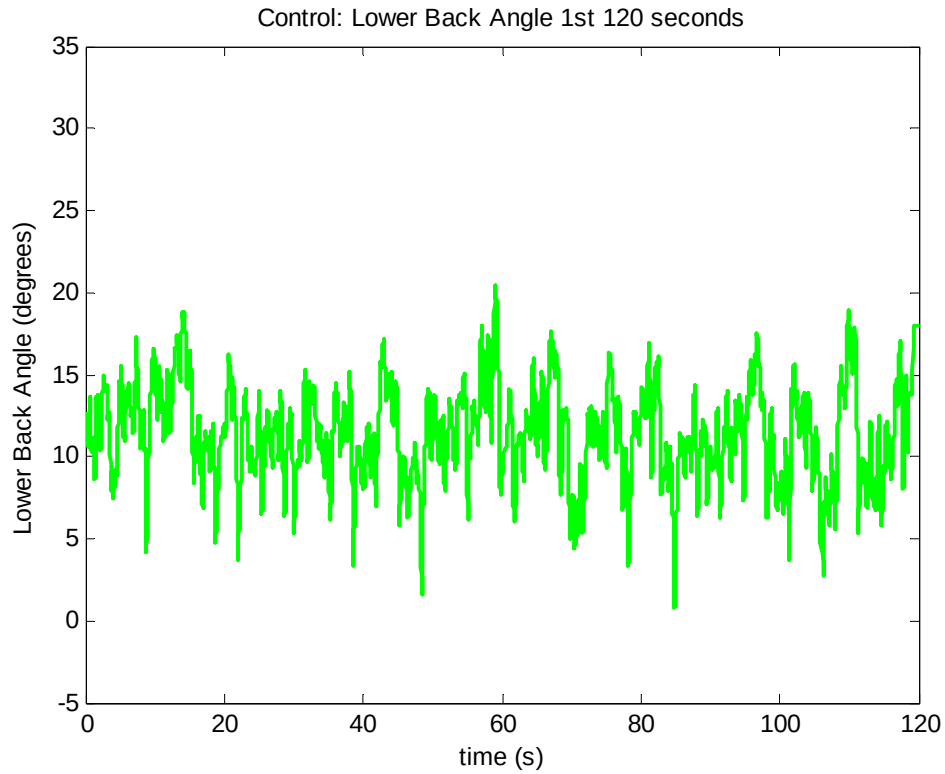


Figure A23. Control Back Camera Lower Back Angle 1st 120 seconds

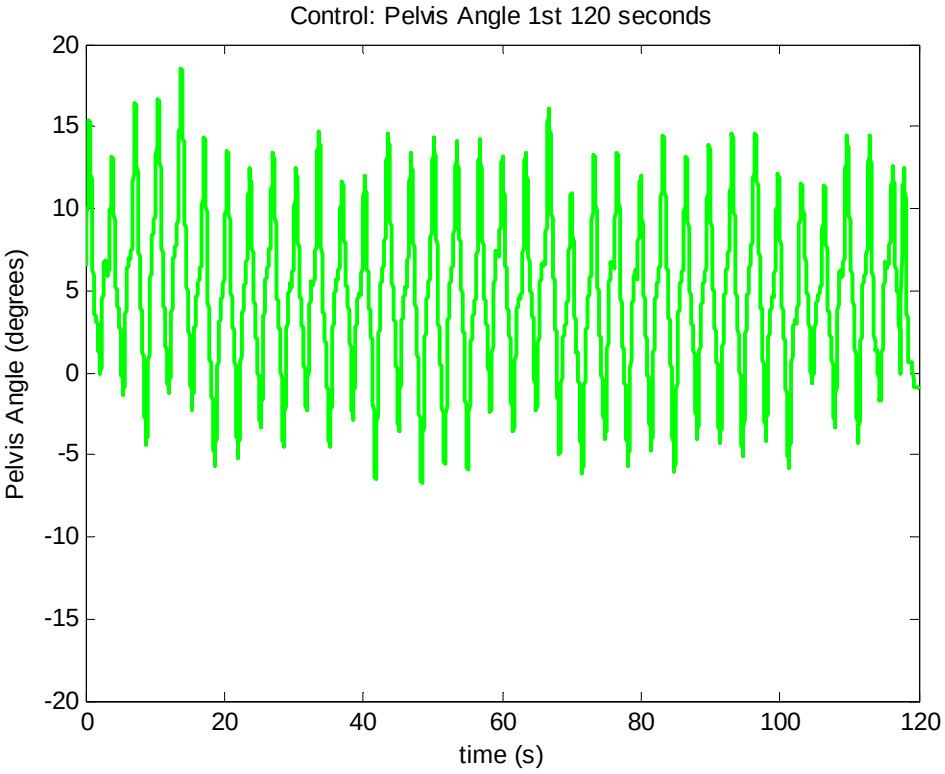


Figure A24. Control Back Camera Pelvis Angle 1st 120 seconds

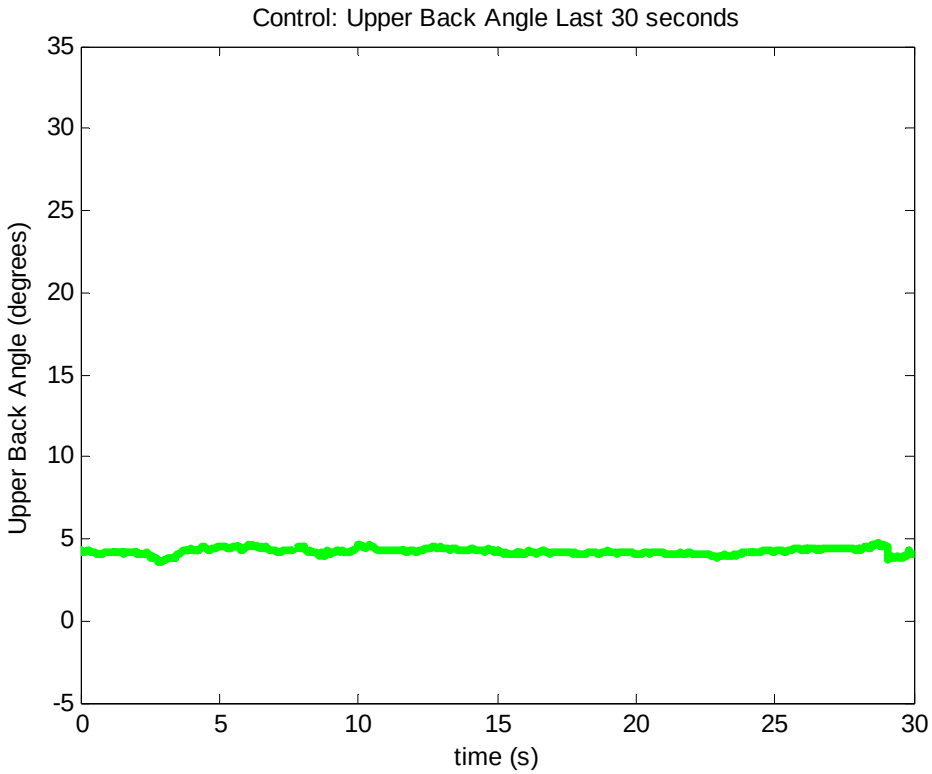


Figure A25. Control Back Camera Upper Back Angle Last 30 seconds stationary

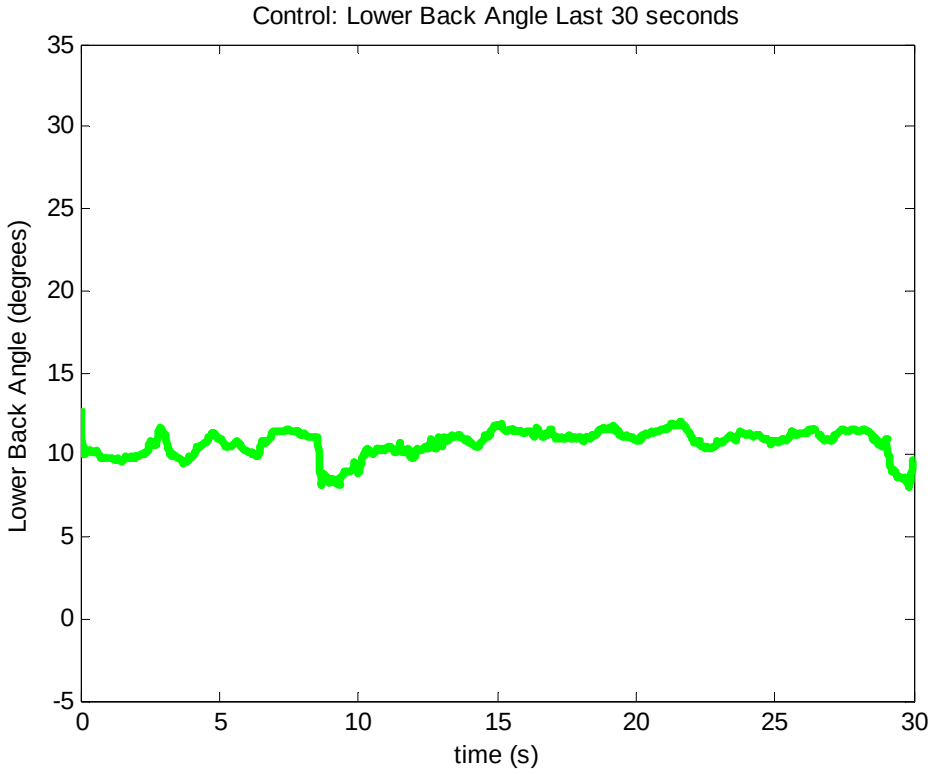


Figure A26. Control Back Camera Lower Back Angle Last 30 seconds stationary

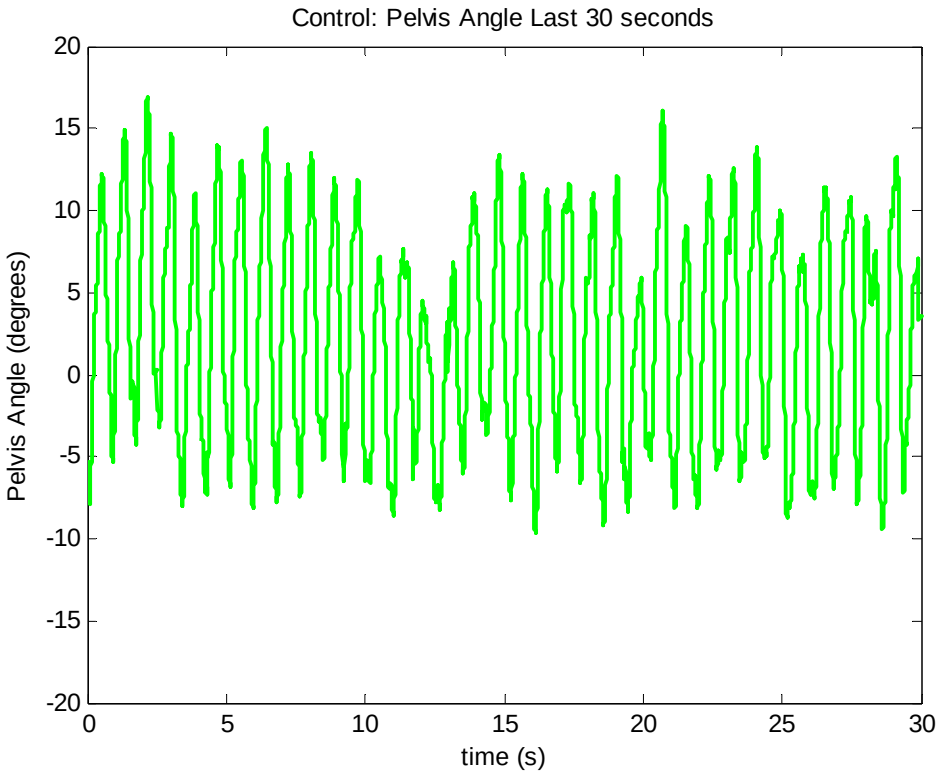


Figure A27. Control Back Camera Pelvis Angle Last 30 seconds stationary

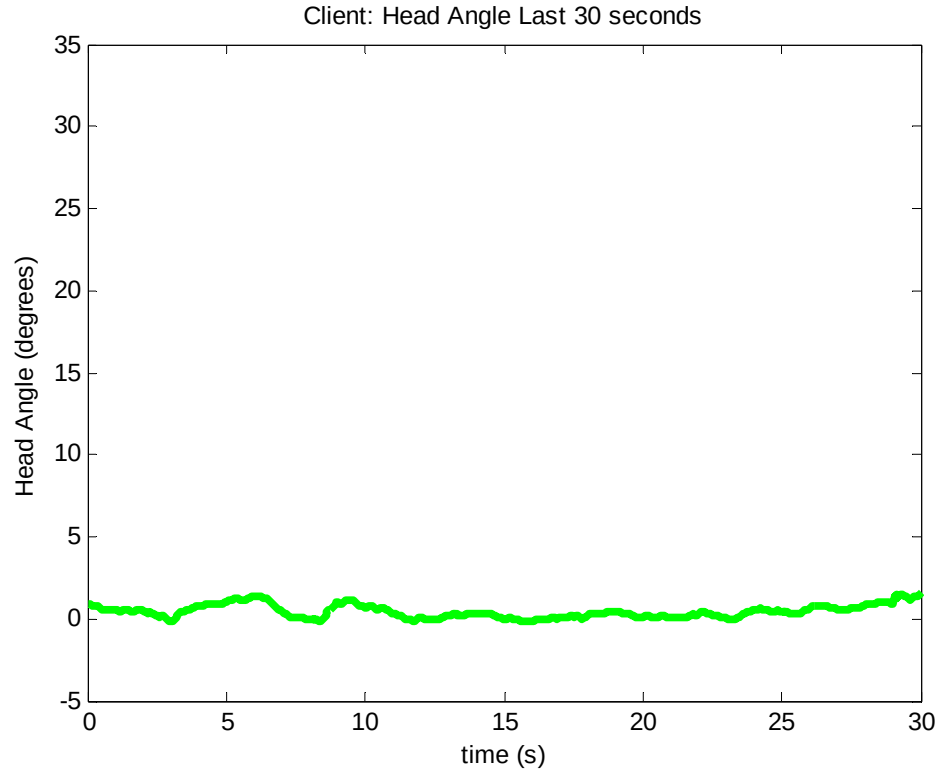


Figure A28. Control Back Camera Head Angle Last 30 seconds stationary

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