ABSTRACT

The Impact of the Motion of a Mechanical Horse on the Pelvic Motion and Postural Control of Children with Autism Spectrum Disorder

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There are currently numerous interventions available to treat individuals of all ages and lifestyles with autism spectrum disorder, or ASD; but one that has become increasingly popular in recent years has been equine-assisted activities and therapy (EAAT) due to the numerous physical, mental, and social benefits it may provide. However, it may not be possible for all individuals to partake in EAAT for several reasons, which may include not having easy access to a facility which provides these services, the individual possessing a fear of live horses, or if the severity of the individual's disability would make this type of intervention unsafe. Therefore, Dr. Brian Garner of Baylor University created the MiraColt, a mechanical horse which simulates the motion of a real horse walking in the forward direction, which could possibly be used as an intervention method for these individuals. Dr. Garner and his team conducted a research study which involved nine children, aged 6-12 years, with diagnosed autism spectrum disorder, riding the MiraColt over a series of several treatment, control, and assessment sessions. Balance, gait, pelvic motion, brain waves, speech, and behavior were evaluated in all of these children, however, this thesis focuses solely on the pelvic motion and postural control data of four of the children involved in the study. After data was collected, it was run through the Nexus 2.0 program, then through a code created by an undergraduate engineering student at Baylor University. Data points from these riding sessions were then graphed, and pre- and post-treatment pelvic motion synchronization were compared. From a qualitative analysis, improvements in synchronization of participant pelvic motion with the motion of the MiraColt were seen from the pre-treatment to post-treatment assessment sessions. This overall improved synchronization of pelvic motion and the motion of the MiraColt from pre-treatment to post-treatment implies improvements in coordination of pelvic motion and strengthening of the muscles of postural control, which are primarily located in the trunk, abdomen, and back. These improvements could possibly be transferrable to improvements in postural control in riding a real horse, participation in sports activities, and various activities of daily living, including sitting, standing, walking, and running. Further research is highly encouraged in order to confirm these suggestions, as this can help advance our knowledge to help individuals of all ages with ASD and other disabilities to have the best quality of life possible.

APPROVED BY DIRECTOR OF HONORS THESIS:

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DATE: _______________________

THE IMPACT OF THE MOTION OF A MECHANICAL HORSE ON THE PELVIC MOTION AND POSTURAL CONTROL OF CHILDREN WITH AUTISM SPECTRUM DISORDER

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By

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CHAPTER ONE

Introduction and Background

Autism Spectrum Disorder, or ASD, is one of the most prevalent disorders in the United States today, according to the Centers for Disease Control and Prevention (CDC, 2012; Hawkins et al., 2014). Individuals diagnosed with ASD may experience significant deficits in social and communication skills, making it difficult for those affected to have successful interactions with their peers. In addition to social deficits, a lack in gross and fine motor capabilities is often another symptom of ASD (Hawkins et al., 2014). These motor deficits may include, but are not limited to, balance deficiencies, postural instability, motor coordination limitations, and repetitive, stereotypical movements. All of these challenges may place greater stress on the family members or caregivers responsible for an individual diagnosed with ASD, and the individual themself may feel misunderstood by those around them (Gabriels et al., 2012).

In order to strive to improve the individual's quality of life, various types of treatment may be sought out. There are a wide variety of intervention methods used to treat individuals with ASD, which may include individual or group therapy to work on social skills, or a type of treatment geared towards improving motor skills, some of which include walking, running, swimming, or muscle strength training (Sowa & Meulenbroek, 2012). One type of treatment modality which has grown in popularity in recent years is equine assisted activities and therapies (EAAT). In this type of intervention, the individual may participate in activities both on the ground (petting the horse, leading, grooming, and tacking up the horse and untacking) and while riding (different stretches and activities included while riding) (Lanning et al., 2014).

Multiple studies have been conducted which examine the extent to which EAAT may benefit individuals with ASD and other disorders, many of which have found positive results which are both statistically and clinically significant. For example, in one study which measured the effects that therapeutic horseback riding had on 42 children with ASD, they saw improvements in self-regulation (irritability, lethargy, stereotypic behavior, and hyperactivity), adaptive expressive language skills, motor skills, and motor planning skills as soon as the third week of intervention (Gabriels et al., 2012). Similarly, in another study which measured the effects of 9 weeks of equine-assisted activities on 13 children diagnosed with ASD, researchers found that participants showed improvements in social, physical, and school functioning, as well as overall mental health (Lanning et al., 2014). Furthermore, the parents of the children involved in this particular study reported increases in attention and decreases in distractibility as a result of the intervention (Lanning et al., 2014). In addition, a smaller study conducted found that equine- assisted therapy helped improve the gross motor skills of two children with ASD, which included improvements in body coordination and strength and agility (Hawkins et al., 2014).

These benefits have been attributed to several factors related to the involvement of equines in the treatment. One possible explanation for such benefits may be due to the human- horse interactions that take place during these sessions (Gabriels et al., 2012). During EAAT sessions, the children are often encouraged to verbalize instructions to their horse by therapeutic horseback riding instructors, which may carry over to improving social and communication skills outside of riding (Gabriels et al., 2012). Furthermore, some parents of the children who took part in these studies also noted the calming effect that riding had on their children, which is theorized to be due to the sensory input horses may provide to children with ASD, including the warmth that the horse produces while moving (Gabriels et al., 2012). Another consideration that may correspond with the motor skill improvements seen in these EAAT sessions is the similarities that exist between the pelvic motions while riding and walking (Garner & Rigby, 2015). Using 3D motion capture technology, Dr. Brian Garner of Baylor University conducted a study comparing the pelvic motions of 6 able-bodied children while walking and while riding a horse (Garner & Rigby, 2015). Dr. Garner and his team found several similarities in the pattern and amplitude of the pelvic motions between walking and riding, including in anteroposterior displacement, superoinferior displacement, mediolateral displacement, and list angle (Garner & Rigby, 2015). Therefore, the findings in this study promoted the idea that if these similarities in pelvic motion do exist, then EAAT may be a valuable option for improving motor capabilities in individuals with disabilities who may not be able to move naturally on their own (Garner & Rigby, 2015).

Based on these findings and other preexisting literature on EAAT, Dr. Garner and his team created the MiraColt, which is a mechanical horse-riding simulator designed to mimic the motion of a horse walking in the forward direction. This was created in the hopes of providing an option to help individuals experience the benefits of EAAT, which includes various physical benefits such as improvements in balance, normal walking gait, and postural control, to those who may not have a therapeutic horseback riding program easily accessible to them, or for those who may possess a fear of live horses (Benoit, 2011). The MiraColt contains an immobile base of support with the seat area positioned above it, which moves in a repetitive pattern similar to how the back of a real horse moves when walking (Benoit, 2011). In its initial testing, it was found that the MiraColt is capable of producing similar kinematic motion to that of a real horse, and therefore has the capability to possibly bring about similar benefits to that of EAAT (Barrett, 2018). Based on these findings, Dr. Garner and his team of researchers are currently conducting a study to examine what effects the MiraColt can have on the gait, balance, posture, coordination, pelvic motion, language capabilities, behavior, and general well-being of children aged 6-12 years with ASD.

The focus of this thesis will be on the collection and analysis of pelvic motion and postural control data of participants while riding the MiraColt in the Garner Baylor Autism Study (GBA Study). Postural control is a very important measure which relates to sensorimotor processing, balance, and core stability of the participant (Garner et al., 2022). While riding either a real or mechanical horse, the rider must coordinate their trunk and pelvis motion in response to the motion of the horse. In order to assess this in GBA study participants riding the MiraColt, posture markers were placed on the pelvis, and these data points were compared to that of the mobile seat of the mechanical horse. Furthermore, these data points were collected at the participant's initial riding session in the GBA study, which were compared to the participant's final riding session in the study in order to assess the changes that may have occurred during the intervention period.

The remainder of this thesis is divided into three subsequent chapters: Methods, Results, and Discussion and Conclusion. The Methods chapter will include information regarding the process of data collection and analysis of postural control data of participants in the GBA study. Next, the Results chapter will include various graphs and charts which are the product of the data analysis performed in the GBA study. Finally, the Discussion and Conclusion will address the findings from the data outlined in the Results chapter. This final chapter will also explain the meaning of such findings, and include suggestions for further research in the future.

CHAPTER TWO

Methods

This chapter of the thesis will outline the process of data collection in the GBA study, with a special focus on the collection and analysis of postural control data of the participant as compared to the motion of the MiraColt. The GBA team recruited participants with ASD from the Waco, Texas community for experimental sessions at the Baylor Research and Innovation Collaborative (BRIC). These experimental sessions included both assessment and treatment sessions, with treatment sessions including both “sleepy” horse and “wakey” horse. Postural control data was taken during each assessment sessions, as well as during “wakey horse” riding sessions. Postural control data analysis focused on comparing the magnitude, phase, and basic motion pattern of the participant’s pelvic swing and the mobile seat of the MiraColt. By analyzing this, members of the GBA team can see how well participants are following with the motion of the MiraColt. Lack of coordination with the motion of the mechanical horse may have been seen if the participant was anticipating the motion and therefore getting ahead of it, or falling behind the motion and are therefore getting thrown around.

Depending on the participant’s availability, data collection for this study took approximately sixteen weeks to complete per child at the Baylor Research and Innovation Collaborative in Waco, Texas. The children came in about ten times to ride a moving mechanical horse, which was referred to as “wakey” horse, for twenty-minute riding sessions. During assessment days, participants sat facing forward on the moving mechanical horse for the entire twenty-minute riding session; but on treatment days, designated undergraduate and graduate students played various games with the children while they rode, including darts, playing catch with a ball, various puzzles, and more. GBA team members also had the participants face four different directions while riding the mechanical horse during treatment sessions. Furthermore, we had a control, which we referred to as “sleepy” horse, which was same mechanical horse used for “wakey” horse, except we did not turn this one on so that the seat was immobile. During these treatment sessions, students also played various games with the children to keep them engaged, and also had them face four different directions. Participants rode the “sleepy” horse between five to ten times, depending on when in the study they participated. This control was not used during assessments, just treatment sessions.

Additionally, data was collected before and after participants rode during treatment sessions on their gait and balance, as well as their pelvic swing and brain activity while actually riding. To measure gait, participants were asked to walk across a Strideway Gait Mat ten times before and after each session. Furthermore, participants were asked to stand with feet together and feet tandem twice, using a balance pad built into the floor which measured their stability during 25-second intervals. In order to measure the postural control of participants while riding, GBA team members attached motion capture markers to a belt which sat on the participant’s pelvis while they rode, as well as two motion capture markers to the mobile seat portion of the MiraColt, and two motion capture markers on the stationary base portion of the MiraColt. The room in which data collection took place also had numerous cameras set up around the area in order to track the motion of the markers through space over the twenty-minute riding session.

Motion capture data collection was taken during assessment sessions and "wakey" horse treatment sessions, but not during "sleepy" horse since the mechanical horse was not moving, and therefore there would not be any pelvic swing data to be collected. EEG data was also collected during all treatment and assessment sessions by a graduate student who was proficient in using this technology.

Assessment sessions were structured very similarly to treatment sessions, with some additions and adjustments as needed. The first assessment session took place before the participant had completed any treatment sessions, one was at the very end of all treatment sessions, and one to three were dispersed during "sleepy" and "wakey" horse sessions, depending on when the participant joined the study. Assessment sessions measured gait, balance, pelvic swing, and brain activity as usual; but participants were also tested on flexibility and core strength as well. During assessment sessions, speech and behavior assessments were also conducted to see if the MiraColt intervention benefited the children in this area. As previously mentioned, participants were also asked to sit quietly facing forward for the riding portion of the assessment instead of switching directions or playing games as they did during treatment sessions.

The Nexus 2.0 software on a laptop located in the Baylor Research and Innovation Collaborative was used for motion capture data analysis. Before using this software, though, the videos of the participant's assessment sessions were viewed, as these are the sessions that data processing and analysis were performed on. While examining these videos, two segments where participants were riding particularly well were singled out. The criterion for these segments included the participants facing forward while riding and not flailing about. These segments ranged from approximately one to two minutes long, but some were shorter depending on how well the participant was cooperating on that particular day. For example, if a participant came in for data collection on a day in which they had been playing outside with friends during the summer, or were very tired after a long day at school, their postural control may not have been as stable as another day that was not as exhausting or stressful. After these segments were identified, the motion capture file in the Nexus software was opened for the assessment session that was being processed on that particular day. Once the file was opened, PlugInGait FullBody was clicked on and the file was labelled with the subject's code, which was AH2(participant number). The subsequent step was to click on Reconstruct 2 Cam, which identified the motion capture markers as data points in space. Then, the file was trimmed to the desired time interval in which the participant was riding well, which was identified by watching the video recordings. Next, the data points were labelled uniformly across all participants and assessments as follows:

- LPSI and RPSI: left and right posterior pelvis of child participating
- LSHO and RSHO: left and right points on mobile portion of MiraColt
- C7 and T10: left and right points on stationary portion of MiraColt

Then, any possible gaps in the data were identified, and were filled in as necessary using the spline and pattern fills. Once this was completed, all six data points were selected using the Ctrl key, and the data points were exported to an Excel spreadsheet, where an engineering student then ran the points through their code in order to obtain analyzable data from the participant's motion capture material.

CHAPTER THREE

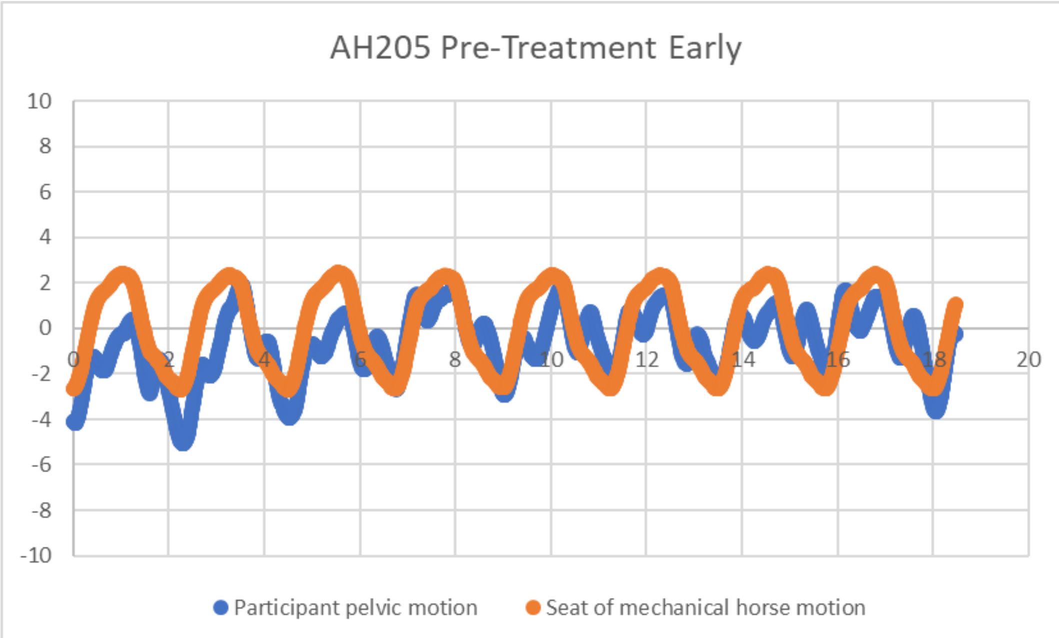
Results

This chapter of the thesis will include a series of graphs for four different participants in the GBA study which show the participants' pelvic motion in relation to the motion of the seat of the mechanical horse while riding. Each of these participants, with the exception of AH211, have four motion capture graphs attributed to them, which span approximately sixteen seconds each. Due to an equipment malfunction during data collection, participant AH211 has a total of two graphs as opposed to four. The first two graphs (one for AH211) present data from the first assessment session, which occurred prior to the multi-week treatment sessions, and the latter two graphs (one for AH211) present data from the final assessment session, which occurred after all treatment sessions had been completed. The first graph from each assessment session reports data recorded during the early portion of the twenty-minute riding session. The second graph from each assessment session reports data recorded during the late portion of the riding session. For participant AH211, data was only obtained from the initial half of each of the two assessments due to an equipment malfunction in the lab, which is why this participant only has a total of two graphs in this thesis as opposed to four. The graphs are labelled as follows:

- First half of initial assessment: Pre-Treatment Early
- Latter half of initial assessment: Pre-Treatment Late
- First half of final assessment: Post-Treatment Early
- Latter half of final assessment: Post-Treatment Late

Graphs are presented in chronological order of data collection, with AH205 being the earliest and AH211 being the most recent data collected. Additionally, it is noteworthy that AH205 is a female participant, while AH209, AH210, and AH211 are male participants. Data presented in the graphs can be found on the next seven pages of this thesis.

AH205:


AH205 Pre-Treatment Early
10
8
6
4
2
0
-2
-4
-6
-8
-10
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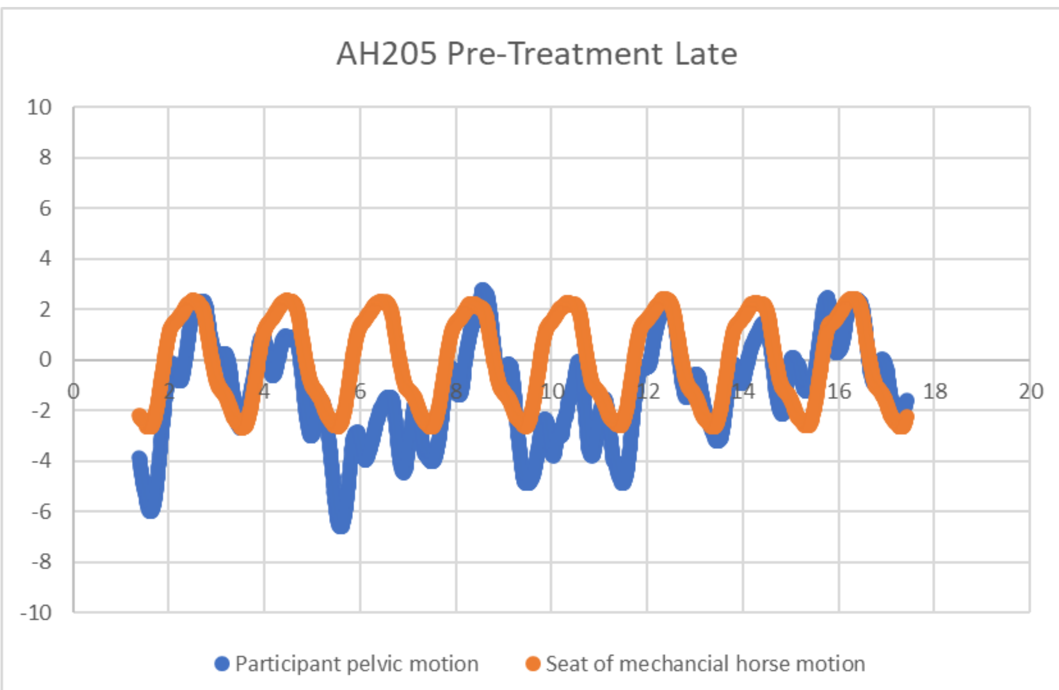
8
10
12
14
16
18
20
Participant pelvic motion
Seat of mechanical horse motion


AH205 Pre-Treatment Late
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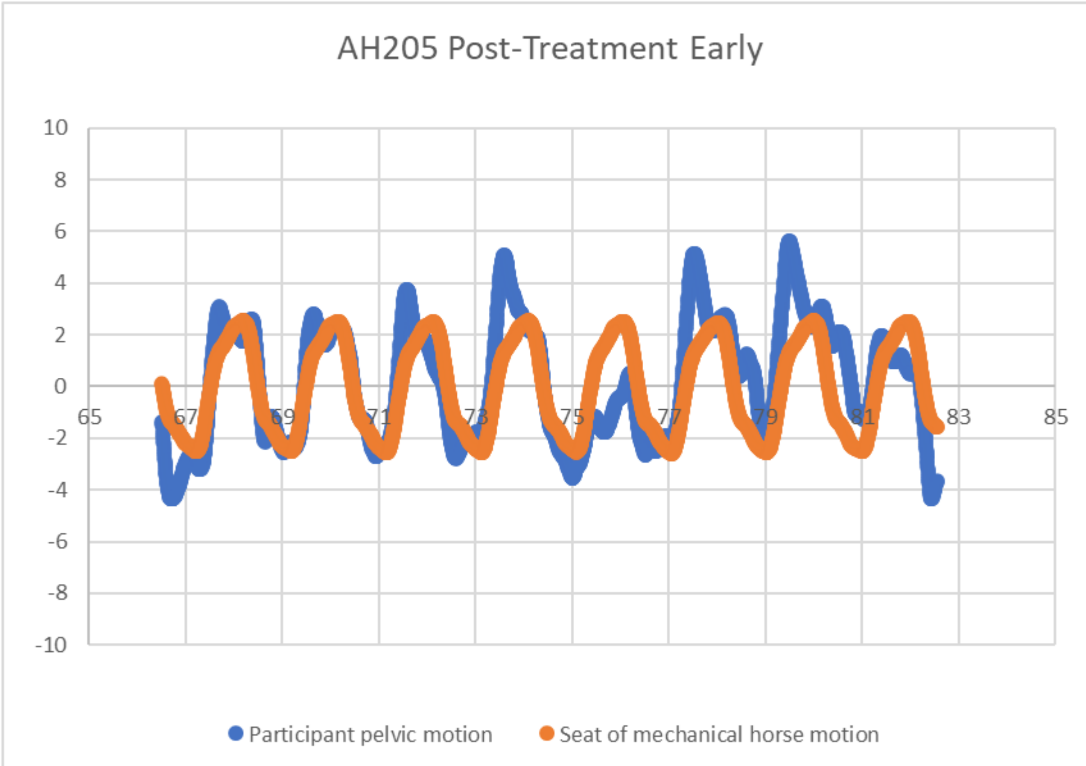
Participant pelvic motion
Seat of mechancial horse motion


AH205 Post-Treatment Early
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6
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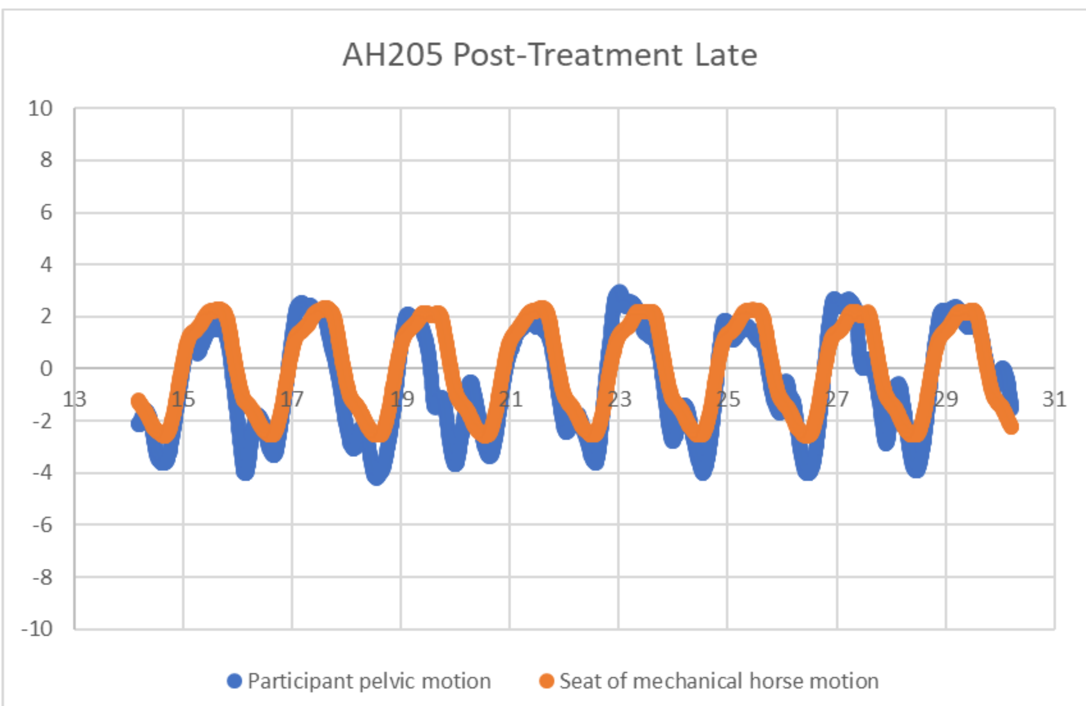
-2
-4
-6
-8
-10
65
67
69
71
73
75
77
79
81
83
85
Participant pelvic motion
Seat of mechanical horse motion


AH205 Post-Treatment Late
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6
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2
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-2
-4
-6
-8
-10
13
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17
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21
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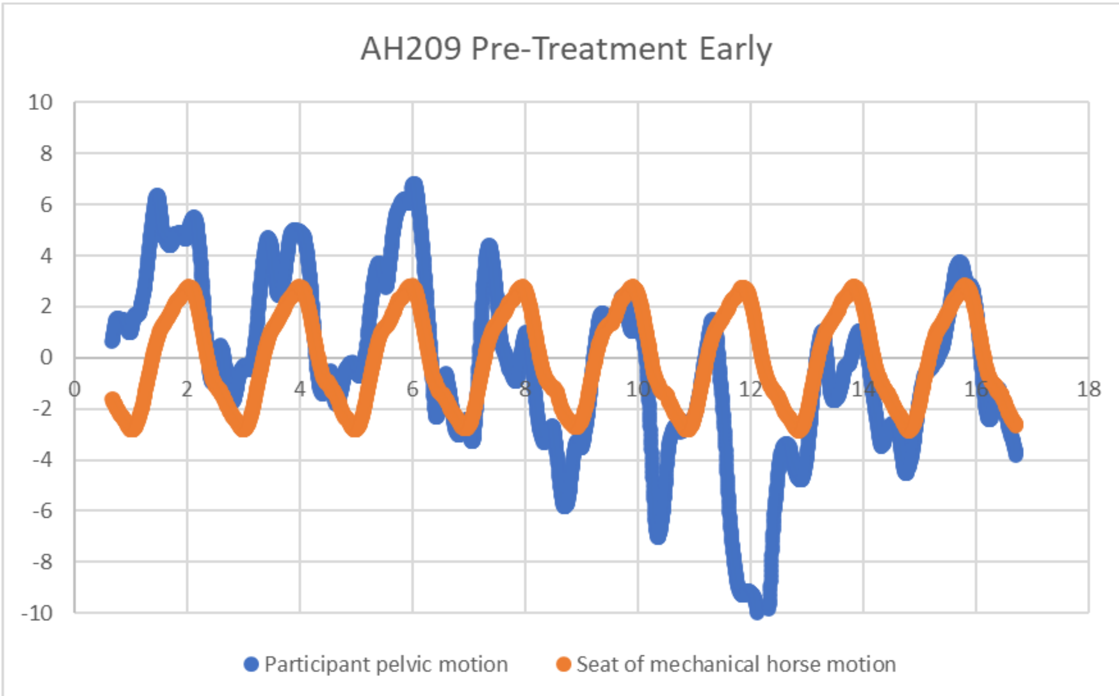
27
29
31
Participant pelvic motion
Seat of mechanical horse motion

AH209:



AH209 Pre-Treatment Early
10
8
6
4
2
0
-2
-4
-6
-8
-10
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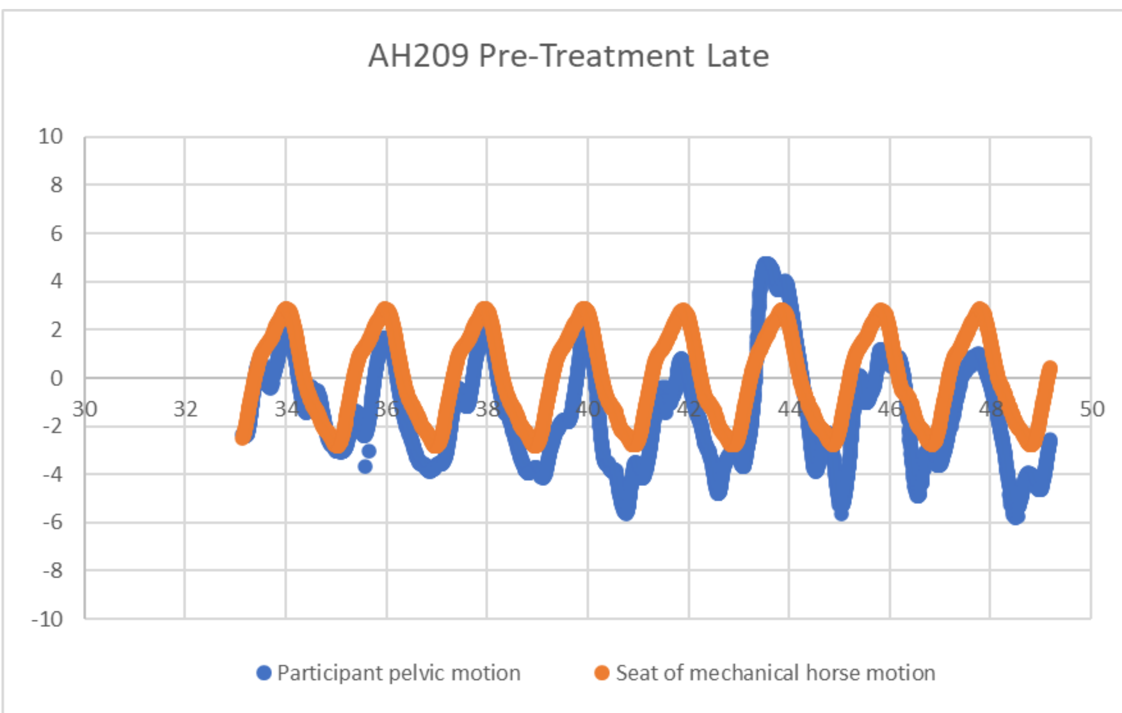
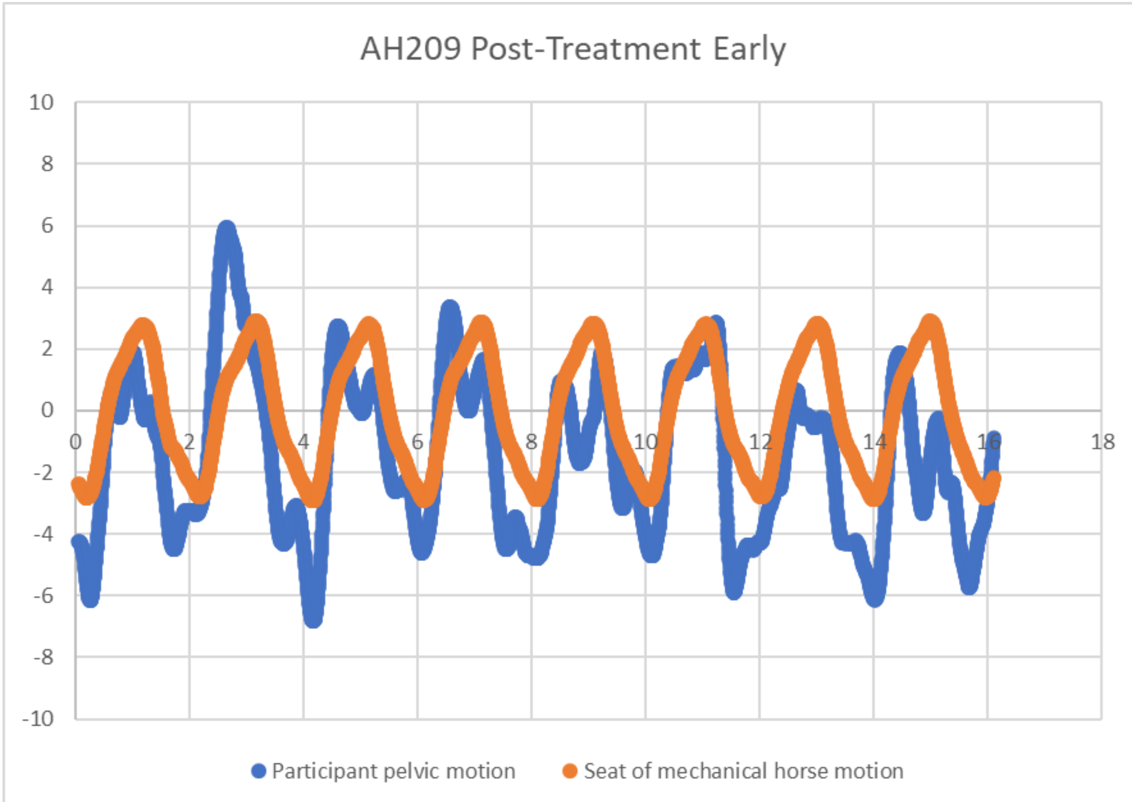
8
10
12
14
16
18
Participant pelvic motion
Seat of mechanical horse motion



AH209 Pre-Treatment Late
10
8
6
4
2
0
-2
-4
-6
-8
-10
30
32
34
36
38
40
42
44
46
48
50
Participant pelvic motion
Seat of mechanical horse motion


AH209 Post-Treatment Early
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-4
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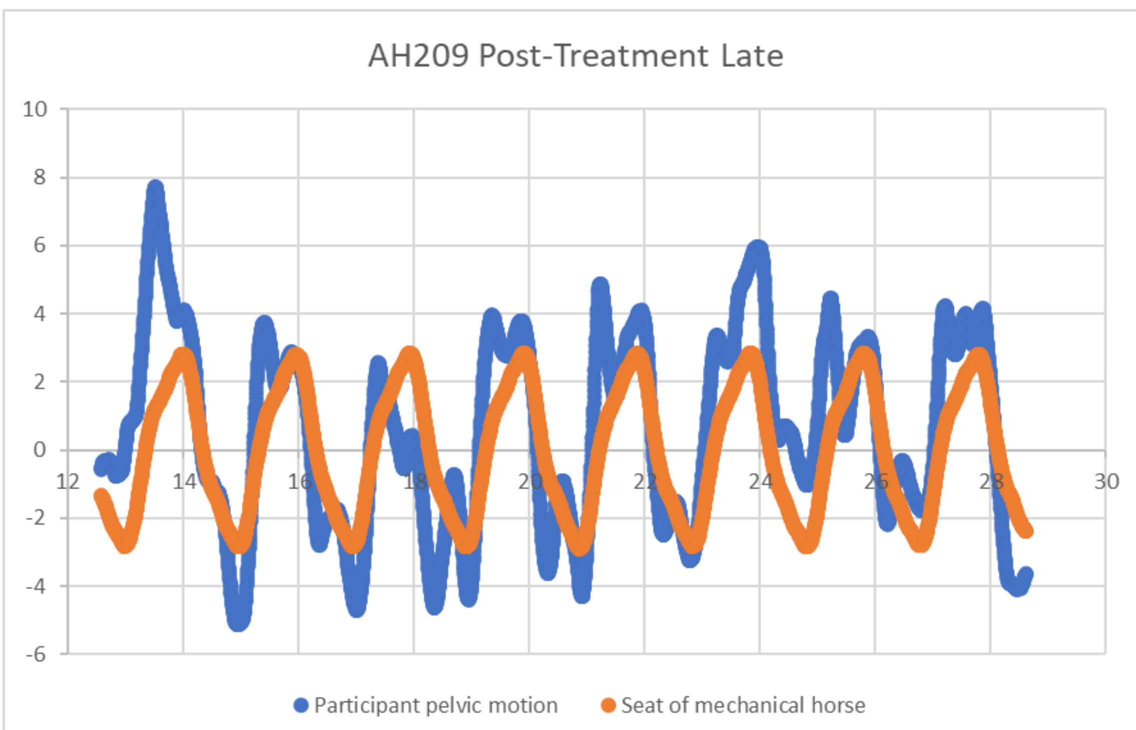
16
18
Participant pelvic motion
Seat of mechanical horse motion


AH209 Post-Treatment Late
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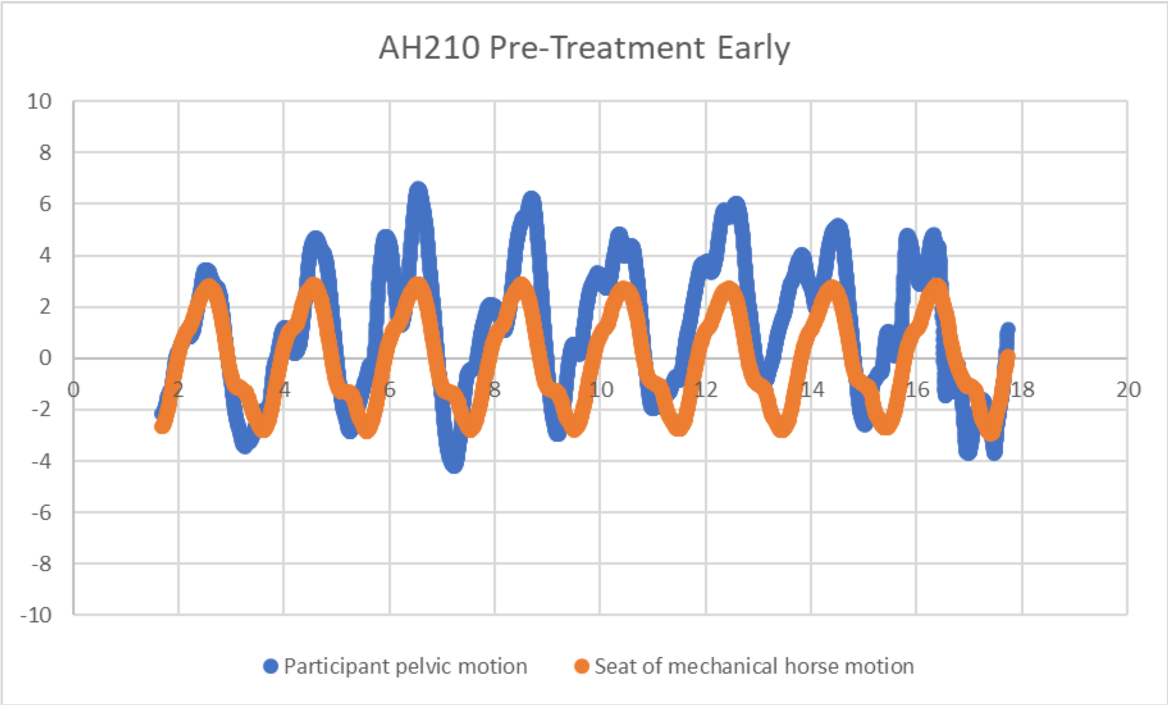
8
6
4
2
0
-2
-4
-6
12
14
16
18
20
22
24
26
28
30
Participant pelvic motion
Seat of mechanical horse

AH210: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2
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-2
-4
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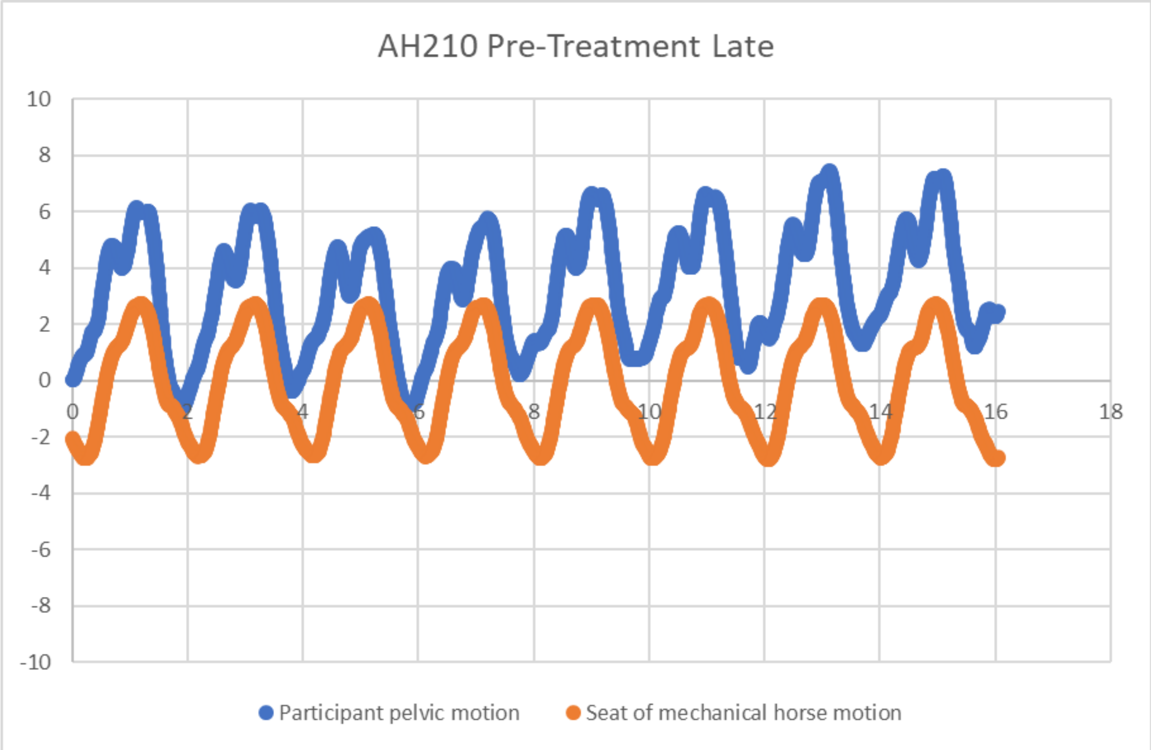
18
20
Participant pelvic motion
Seat of mechanical horse motion


AH210 Pre-Treatment Late
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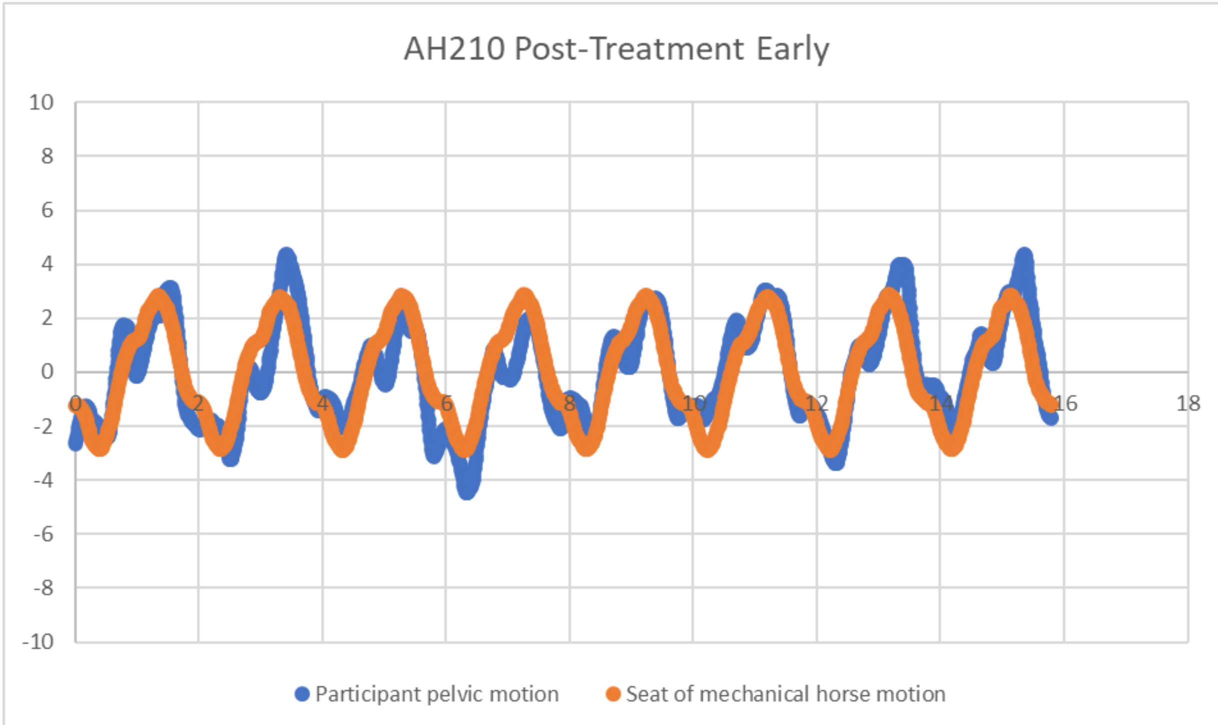
Participant pelvic motion
Seat of mechanical horse motion



AH210 Post-Treatment Early
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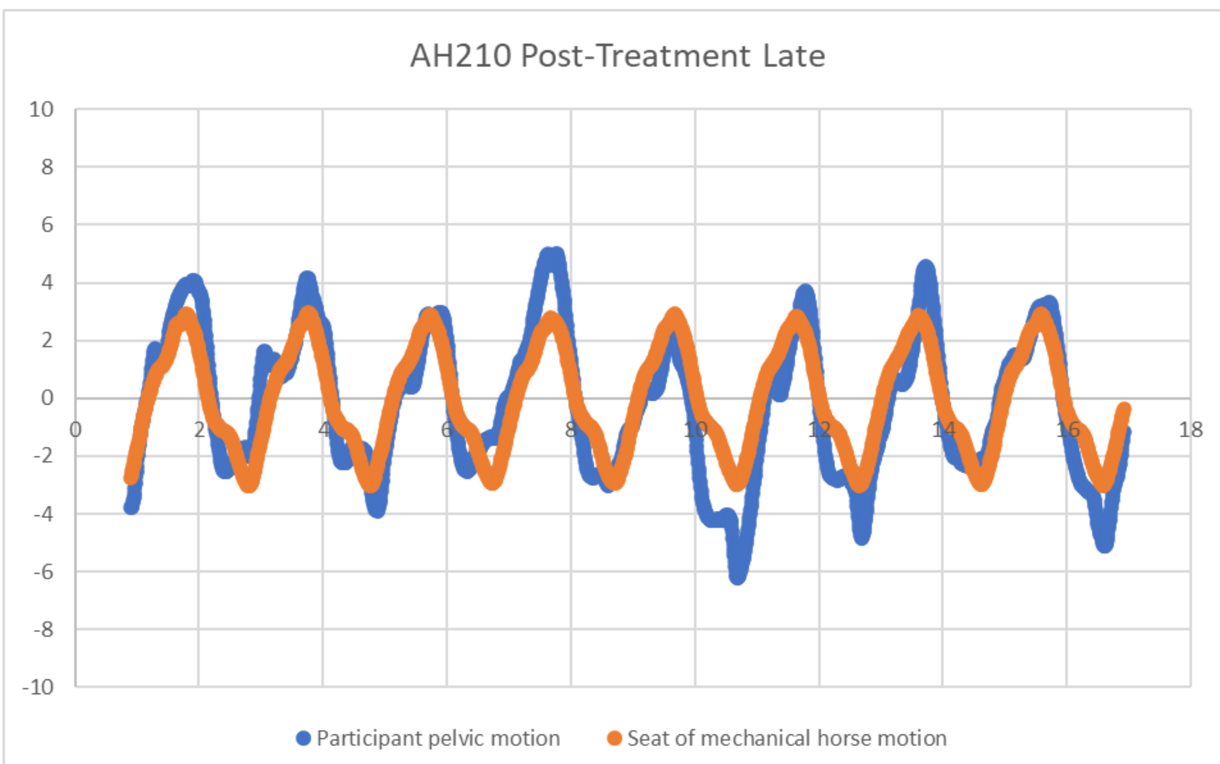
Participant pelvic motion
Seat of mechanical horse motion



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6
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8
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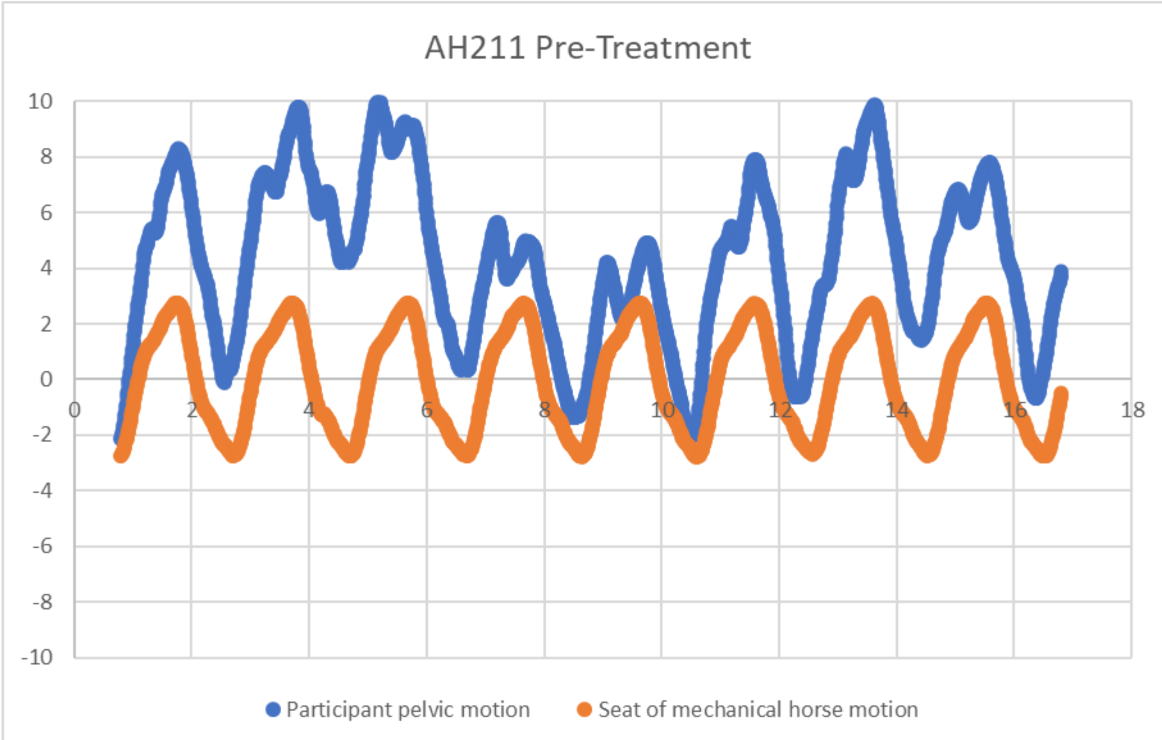
Participant pelvic motion
Seat of mechanical horse motion

AH211:


AH211 Pre-Treatment
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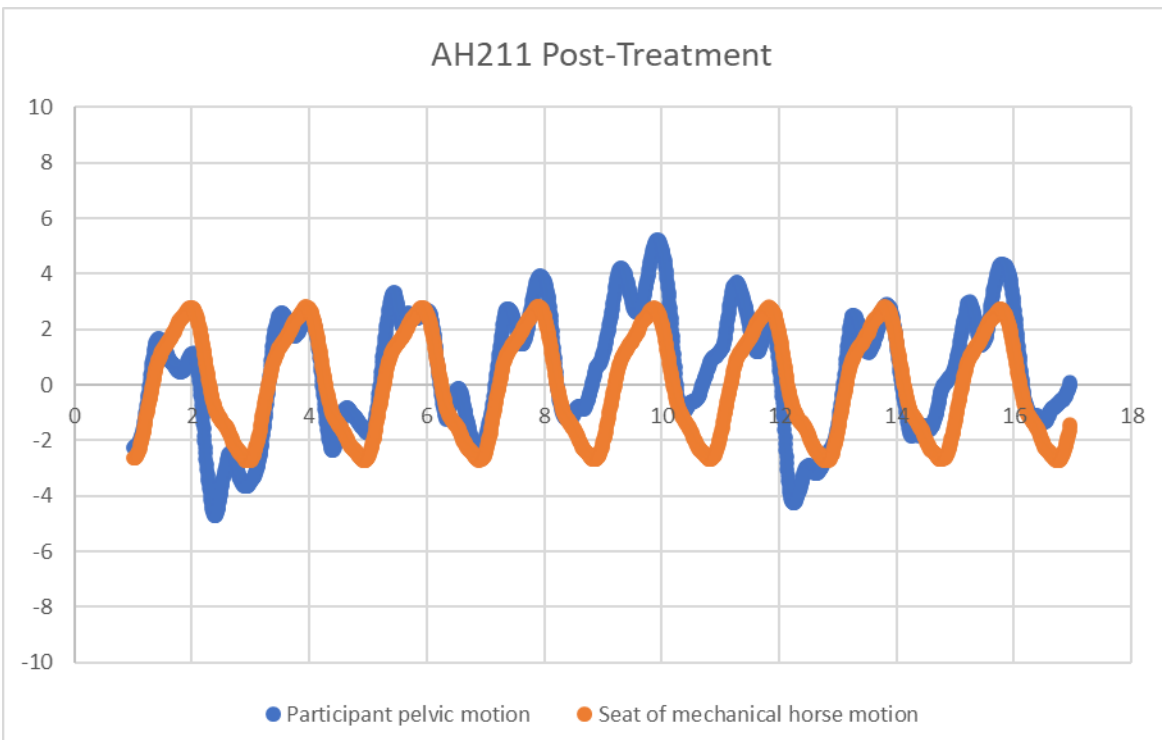
Participant pelvic motion
Seat of mechanical horse motion


AH211 Post-Treatment
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Participant pelvic motion
Seat of mechanical horse motion

CHAPTER FOUR

Discussion and Conclusion

In the fourth and final chapter of this thesis, the data presented in the graphs in the Results chapter will be analyzed and discussed. In addition, suggestions for future studies will be outlined so that they may improve in ways that the GBA study lacked in the area of pelvic motion and postural control. The thesis will finish with final conclusions being drawn regarding the motion capture data analyzed and call for further research on this topic in order to further investigate clinical implications in order to improve the lives of many individuals with ASD and other disabilities as well.

By conducting a qualitative analysis of the graphs presented in the Results chapter of this thesis, one can see improved synchronization and coordination between the participant pelvic motion and the powered seat motion of the mechanical horse from the pre-treatment assessment sessions to the post-treatment assessment sessions for each of the four participants whose motion capture data was included in this paper. Differences between the early and late portions of the riding sessions are more apparent in some participants than others, and could be attributed to fatigue as the treatment session goes on, or if the late portion shows better synchronization than the early portion, then this may imply that the participant needed some time to warm-up for the day. These noted overall improvements in synchronization of the participant pelvic motion with the MiraColt seat motion from pre-treatment to post-treatment implies improvements in coordination of pelvic motion and strengthening of the muscles of postural control, which are primarily located in the trunk, abdomen, and back. These improvements could possibly be transferrable to improvements in postural control in riding a real horse, participation in sports activities, and various activities of daily living, including sitting, standing, walking, and running. Further research is highly encouraged in order to confirm these suggestions.

Furthermore, there are some limitations of this study, especially specific to the area of pelvic motion and postural control data. First, only data from four participants was examined in this thesis. The GBA study itself had a total of nine participants; however, some errors were encountered during data processing in the Nexus software which limited the number of participants whose data was able to be processed further and analyzed for this thesis. The COVID-19 pandemic also hindered the amount of participation in the GBA study, since most of the data collection took place between the years 2020-2022. In order to make the findings in this study related to pelvic motion and postural control more reliable, a greater number of participants is suggested in future research projects. Another point to note is that the graphs presented in the results chapter only show approximately sixteen seconds each in assessment sessions that are twenty minutes long. In each of these assessments, there were areas in which participants were riding “well”, which were the portions which were selected for use, but when working with children, especially those with disabilities, it is important to remember that there will be good portions of data collection, as well as those which need to be thrown out due to various different reasons. Therefore, it is suggested that future researchers on this topic analyze more than just 32 seconds per assessment in order to get the most accurate, unbiased results possible. Future researchers should also consider analyzing data at different portions during treatment in order to see the progression of coordination of pelvic motion and strengthening of postural control muscles over the course of the intervention. Such analysis was not included in this thesis because the riding portion of the treatment sessions involved participants engaging in other activities while riding, including facing four different directions and playing games with GBA team members, which caused them to move in response to the activity and not just to the moving MiraColt seat.

In conclusion, the MiraColt used in the GBA study at Baylor University is a useful tool for improved coordination of pelvic motion and postural control in children with ASD. Additionally, the use of the MiraColt as a viable treatment option could possibly be transferrable elsewhere, especially in settings where access to a therapeutic horseback riding center with live horses is not attainable or if the participant possesses a fear of horses. This study is a step forward for ASD research, and further research is highly encouraged on this topic using both mechanical and real horses, able-bodied children and adults along with those with ASD, and even individuals with other disabilities. It is possible that the improvements seen in the participants in this study could go on to benefit these individuals' participation in sports, club activities, and activities of daily living, which again, could be investigated further with future research studies. By completing studies like this and furthering our knowledge, we as a society can work towards improving the lives of people of all ages with ASD and other disabilities and help them live meaningful lives in which they may reach their fullest potential.

BIBLIOGRAPHY

Barrett. (2018). Kinematic effects of mechanical horse simulated hippotherapy.

Benoit. (2011). Designing, constructing, and testing a second-generation prototype mechanical hippotherapy horse.

Fournier KA, Kimberg CI, Radonovich KJ, Tillman MD, Chow JW, Lewis MH, Bodfish JW, Hass CJ (2010) Decreased static and dynamic postural control in children with autism spectrum disorders. Gait Posture 32:6–9 Available at: https://www.ncbi.nlm.nih.gov/pubmed/20400311.

Gabriels RL, Agnew JA, Holt KD, Shoffner A, Zhaoxing P, Ruzzano S, Clayton GH, Mesibov G (2012) Pilot study measuring the effects of therapeutic horseback riding on school-age children and adolescents with autism spectrum disorders. Res Autism Spectr Disord 6:578–588 Available at: https://www.sciencedirect.com/science/article/pii/S175094671100158

Garner BA, Rigby BR (2015) Human pelvis motions when walking and when riding a therapeutic horse. Hum Mov Sci 39:121–137 Available at: https://www.ncbi.nlm.nih.gov/pubmed/25436916.

Hawkins BL, Ryan JB, Cory AL, Donaldson MC (2014) Effects of Equine-Assisted Therapy on Gross Motor Skills of Two Children With Autism Spectrum Disorder: A Single-Subject Research Study. Ther Recreation J 48:135-149 Available at: https://search.proquest.com/docview/1553177534?pqorigsite=gschola.

Lanning BA, Matyastik Baier ME, Ivey-Hatz J, Krenek Nancy, Tubbs JD (2014) Effects of Equine Assisted Activities on Autism Spectrum Disorder. J Autism Dev Disord 44:1897- 1907. Available at: https://www.ncbi.nlm.nih.gov/pubmed/24526337.

Lanning, B. A., Rylander, J., Fillmore, P., Ivey, J., Hockett, S., Switzer, R., Lemke, D., Coleman, R., Kantety, V., Garner, B. Balance, Brain, Speech, Kinematic, and Behavioral Effects of a Mechanical Horse-Riding Simulator for Children with Autism. Podium Presentation, Annual International Conference of PATH International, St. Louis, MO. October 29, 2022.

Rylander, J., Hockett, S., Garner, B., Switzer, R., Fillmore, P., Ivey, J., Lanning, B. A., Coleman, R., Katenty, V.. Balance, Brain, Speech, Kinematic, and Behavioral Effects of a Mechanical Horse-Riding Simulator for Children with Autism, International Society for Autism Research (INSAR), Austin, TX, May 11-14, 2022.

Silkwood-Sherer DJ, Killian CB, Long TM, Martin KS (2012) Hippotherapy--an intervention to habilitate balance deficits in children with movement disorders: a clinical trial. Phys Ther 92:707-717 Available at: https://www.ncbi.nlm.nih.gov/pubmed/22247403.

Sowa M, Meulenbroek R (2012) Effects of physical exercise on Autism Spectrum Disorders: A metaanalysis. Res Autism Spectr Disord 6:46–57. Available at: https://www.ncbi.nlm.nih.gov/pubmedhealth/PMH0034339/.

Stins JF, Emck C, Vries EMD, Doop S, Beek PJ (2015) Attentional and sensory contributions to postural sway in children with autism spectrum disorder. Gait Posture 42:199-203. Available at: https://www.ncbi.nlm.nih.gov/pubmed/26028526.