Utilizing a Novel Hippotherapy Simulation for Neuromuscular Therapeutic Intervention in a Resident with Mowat-Wilson Syndrome (MWS)

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Abstract
This study aims to evaluate the efficacy of a Hippotherapy simulation setup (HT-sim) in enhancing physical adaptations rooted in the mind-body connection, preparing patients for real-time Hippotherapy, and providing mental and emotional benefits. The case study focuses on a resident with Mowat-Wilson Syndrome (MWS) whose engagement with HT-sim was monitored over five quarters. Key metrics, including self-realignments (S-R), accordance periods (ACC), and discordance periods (DCC), were analyzed to assess motor control, stability, and synchronization with external stimuli.

Results indicated a clear trajectory of improvement, with a significant increase in S-R and ACC metrics and a decrease in DCC metrics over time. Initially, our resident struggled with stability and self-led postural adjustments, but consistent engagement with HT-sim led to refined motor responses and improved balance. By the final quarters, he demonstrated mastery in maintaining stability, highlighting the effectiveness of HT-sim in fostering neuromotor functions.

The study also explored the emotional and mental benefits of HT-sim, noting reduced physical tension, increased well-being, and enhanced quality of life. The findings support the potential of HT-sim as a preparatory or supplementary intervention for traditional Hippotherapy, offering significant therapeutic benefits in a cost-effective and accessible manner. This research underscores the value of HT-sim in neurorehabilitation, particularly for individuals with conditions like MWS.

The results suggest that HT-sim can be a practical and effective tool for enhancing motor control, stability, and emotional well-being, paving the way for future applications in clinical and therapeutic settings.

A. **General Background**

Introduction to Hippotherapy in Neurological Rehabilitation
Hippotherapy, utilizing the rhythmic and repetitive movements of horses, has shown promise as a therapeutic intervention for individuals with neurological conditions (Bronson et al., 2010). For patients with Mowat-Wilson Syndrome (MWS), which affects core stability and postural control, hippotherapy offers a unique opportunity to enhance daily living capabilities. The dynamic interaction between the patient and the horse stimulates sensory pathways and motor responses, strengthening neuroconnections and improving overall motor function.

Mechanisms and Outcomes of Hippotherapy
Hippotherapy integrates the horse's natural movements to simulate human gait patterns, providing essential neuromotor inputs for gait and mobility rehabilitation. The therapy targets physical

aspects such as balance and posture while also enhancing mental and emotional well-being. Key mechanisms include:

- Engagement with the patient's pelvis and spine, promoting sensory and neuroconnection development.
- Mimicking human gait to aid in gait training and improve mobility.
- Focusing on specific rehabilitative goals with a team approach involving therapists and certified riding instructors.

Hippotherapy offers broad-spectrum benefits, fostering physical, social, cognitive, and psychological improvements, reducing physical tension and emotional stress, and enhancing overall quality of life.

In summary, hippotherapy is a valuable component of neurological rehabilitation, particularly for individuals with Mowat-Wilson Syndrome, by providing targeted sensory and motor stimulation and promoting comprehensive developmental goals.

B. **Background on MWS**

Mowat-Wilson Syndrome (MWS) is a genetic disorder characterized by a constellation of neuromuscular deficits, intellectual disabilities, and developmental impairments, primarily due to disruptions in the ZEB2 gene (Adam et al., 2007). This gene, a key transcription factor, is critical for the development of the neural crest and various brain regions. Disruptions in ZEB2 often present as large deletions or frameshift/nonsense variants, resulting in haploinsufficiency (Quintes 2016). This genetic insufficiency leads to the broad clinical features observed in MWS.

The neuromuscular phenotype of MWS patients includes progressive degeneration of neuromotor abilities due to impaired connectivity between brain regions, stemming from ZEB2 mutations. These mutations impact neural differentiation and guidance, leading to notable balance challenges, abnormal muscle tone, motor planning difficulties, and coordination deficits (He et al., 2018).

Most specifically, the neurological clinical features in MWS are linked to an immature cortical identity of GABAergic interneurons (Schuster et al., 2022). These interneurons, primarily inhibitory, are crucial for maintaining cerebral microcircuit balance. Deficient GABAergic activity is implicated in hyperexcitability and seizure activity, common in MWS patients.

The clinical manifestations of MWS, including neuromuscular impairments and developmental delays, are intrinsically linked to genetic aberrations in the ZEB2 gene. Understanding these genetic disruptions is crucial for developing targeted therapeutic interventions, such as hippotherapy, which may help ameliorate some of the neuromotor challenges faced by individuals with MWS.

C. **MWS Physiology**

Neurodevelopment, Brain Abnormalities, and Epilepsy in MWS

Mowat-Wilson Syndrome (MWS) is a complex genetic disorder caused by disruptions in the ZEB2 gene, which plays a critical role in neural crest cell differentiation and migration, as well as in modulating GABAergic neurotransmission. These genetic abnormalities lead to varied structural and functional impairments, including cerebellar malformations, reduced white matter, and altered neural signals. Such impairments underlie the balance challenges, motor planning issues, coordination deficits, and ataxic-like gait observed in individuals with MWS. The onset of hypotonia, which progresses into hypertonia and potential spasticity, contributes to unstable weight bearing and an imbalanced gait.

Developmental milestones are significantly delayed in MWS, with considerable gaps in achieving sitting, walking, and speech abilities compared to unaffected individuals. While many individuals with MWS may not develop speech, they often possess receptive language skills and can communicate effectively using augmentative and alternative communication (AAC) methods.

The Benefits of Hippotherapy for Neuromuscular Conditions

Hippotherapy (HT) offers multidirectional movement therapies that can significantly enhance gait, balance, and postural control—areas where individuals with MWS often struggle due to their neuromotor challenges. The rhythmic movements inherent to HT aid in sensory integration and help strengthen neurological connections that may be weakened in MWS due to CNS anomalies. Additionally, HT supports the development of communication skills, providing alternative ways for patients to express themselves and interact, which may also alleviate some behavioral issues.

HT provides structured yet dynamic physical engagement, addressing the complex neuromuscular impairments associated with MWS. It supports a wide range of treatment objectives, from improving motor and communication skills to managing psychosocial and cognitive challenges. This therapeutic modality aligns closely with the multifaceted needs of those with MWS, making it an integral part of the treatment landscape for neuromuscular conditions.

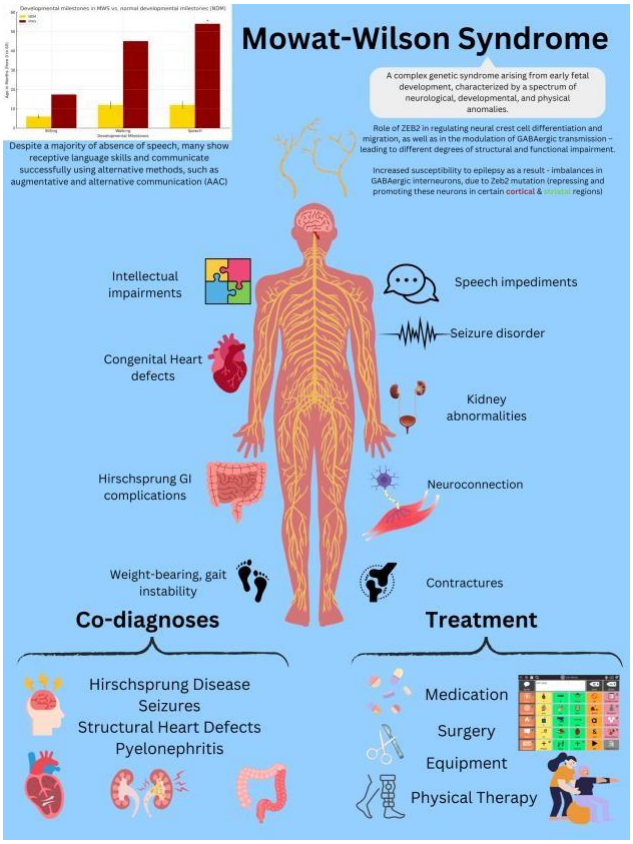

Figure 1. The accompanying infographic provides a visual summary of the MWS spectrum, from neurodevelopmental concerns to psychosocial impacts, and correlates these with the corresponding therapeutic benefits of HT. As observed in the case of our resident and substantiated by a growing body of research, HT stands as a promising adjunct to traditional therapies, aspiring to enrich the lives of those living with Mowat-Wilson Syndrome and similar neuromuscular disorders. The detailed depiction in the infographic of co-diagnoses, treatment modalities, and associated impairments outlines the complexities of MWS and underscores the importance of innovative, integrative therapeutic strategies like HT as a component of a larger regimen of treatment strategies.

D. **SIMULATION THERAPY (HT-sim)**

The hippotherapy simulation internship project, conducted in collaboration with We Can Ride® and Hold Your Horses®, aims to replicate the therapeutic benefits of equine therapy for individuals diagnosed with Mowat-Wilson Syndrome (MWS). This innovative physical therapy program is designed with the following core objectives:

1. Replicate Physical Benefits: The program aims to improve motor skills, coordination, and balance through specialized exercises on an Exercise Stability Ball (ESB) that mimic horseback riding movements.
2. Incorporate Occupational Therapy: Enhancing daily living skills, sensory integration, and fine motor abilities through immersive simulation videos, including POV and 360º experiences, to create sensory-friendly environments.
3. Progressive Motor Conditioning: Gradually condition and shape motor abilities and control, enabling residents to achieve predefined motor skills, crucial for individuals with MWS who have compromised neural development and sensory integration.

4. Strengthen Mind-Body Connections: Simulate the physical movements and sensory experiences of horseback riding to deepen mind-body and mind-muscle connections, enhancing overall therapy outcomes.
5. Ensure Engagement and Enjoyment: Create an engaging and enjoyable therapy experience to promote sustained participation and motivation among residents.

These objectives are rooted in patient-centered care and informed by the latest research in physical and occupational therapies. By simulating the benefits of equine therapy within a controlled environment, this project offers an accessible, effective, and scalable alternative for individuals who cannot participate in traditional hippotherapy.

Design and Implementation of Hippotherapy Simulation (HT-sim)

The HT-sim project is a pioneering approach in the therapeutic management of individuals with mobility and cognitive challenges, such as those presented by MWS. The project, developed with the collaboration of residential supervisors and feedback from professionals, aims to replicate the benefits of traditional hippotherapy within a controlled environment.

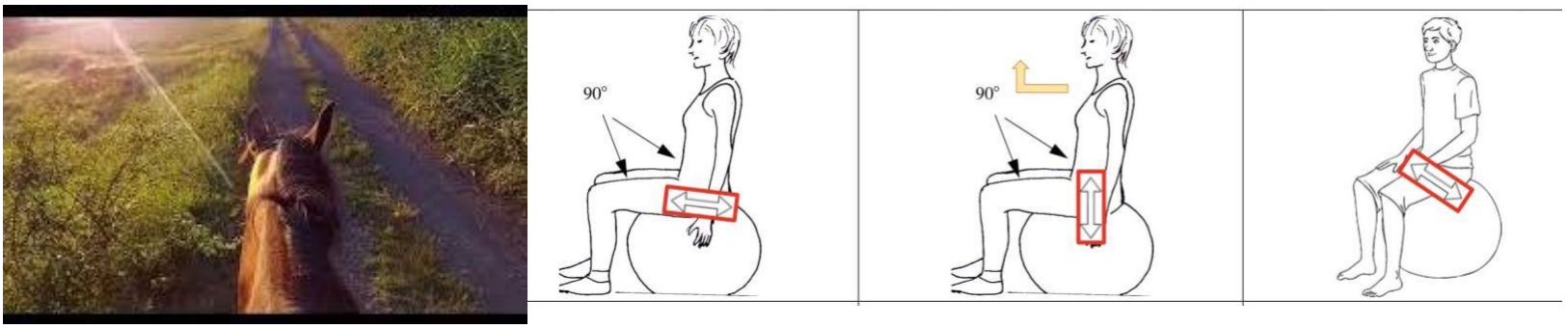

Figure 2. HT-sim begins with a specific setup of a POV horse-riding simulation video, combined with Exercise Stability Ball (ESB) exercises, the integration of which aims to mimic traditional HT.

Strategic Simulation Planning and Core Physical Demands

A collaborative effort with residential supervisors was essential in developing a comprehensive simulation strategy for HT-sim. This included analyzing the core physical demands of horseback riding, such as balance, posture, and motor skill development, and reviewing case studies on HT simulations to inform the program's framework.

Innovative Physical Therapy via HT-simulation

The implementation phase introduced the use of an ESB coupled with POV horse-riding videos to create an immersive therapeutic environment. This approach aims to emulate the dynamics of equine therapy, focusing on stability ball exercises to develop motor skills and enhance balance. The use of ESB and POV videos prioritizes accessibility and engagement, replicating the therapeutic movement of horseback riding in a user-friendly manner.

Empowering Staff with Resources

The project's success relies on empowering staff with comprehensive guides and resources, accessible via the Daily Book and SharePoint (Fig. 2). Real-time updates streamline the intervention process, facilitating a cohesive and informed approach. This collaborative environment ensures effective deployment of HT-sim and fosters continuous improvement through feedback and quality improvement efforts.

Potential Benefits and Mind-Body Connection

The HT-sim project promises numerous benefits by engaging patients in simulated horseback riding activities. These include improved balance, mobility, and posture, as well as positive impacts on mental and emotional well-being. The project adopts a holistic approach, recognizing the interplay between physical movement and psychological health, offering a therapeutic avenue that addresses both dimensions.

In conclusion, the HT-sim project represents an innovative initiative in therapeutic interventions, leveraging simulation to extend the benefits of hippotherapy to individuals unable to participate in traditional sessions. Through strategic planning, innovative therapy delivery, and a focus on the mind-body connection, the HT-sim project sets a new standard for immersive and holistic therapeutic practices.

E. **PARALLELS**

The implementation of a Hippotherapy Simulation (HT-sim) utilizing an Exercise Stability Ball (ESB) and POV video simulation can effectively replicate key aspects of real Hippotherapy (HT) for a neuromuscular patient with severe intellectual disability. This hypothesis is grounded in three key parallels:

1. Pelvic Mobility and Balance Transfer:

The proficiency in executing pelvic rolls, circling, and maintaining balance on the ESB in HTsim is hypothesized to correlate directly with the quality and harmony observed in real HT. The pelvic mobility exercises on an ESB significantly mirror the physical demands and balance requirements encountered in real horseback riding (Uldahl et al., 2021). By replicating these movements, HT-sim promotes the rider's ability to synchronize with the dynamic environment of horse riding, enhancing their balance and coordination skills.

2. Weight Distribution Symmetry:

The ability to distribute weight evenly between the left and right feet during HT-sim exercises is anticipated to predict similar weight distribution in real HT. Balanced weight distribution is crucial in both simulated and actual horseback riding for effective trunk support and overall stability. This practice ensures that the patient develops the ability to manage their body weight effectively, which is essential for posture alignment and preventing compensatory strategies that can lead to musculoskeletal issues.

3. Simplified Core Movement – Pelvic Rolling:
Pelvic mobility is critical in equestrian skills, simplified to the core movement of pelvic rolling. This movement is vital for developing a wide range of motion (ROM) necessary for physical and neuromuscular development. HT-sim aims to engage and strengthen the same muscle groups and motor skills as those used in HT, enhancing proprioceptive feedback crucial for patients with neurological impairments. The mimicry of horseback riding's rhythmic motion in HT-sim can also have a therapeutic effect, contributing to the mental and emotional well-being of the patient.

Recent studies underscore the potential of alternative therapeutic modalities that replicate traditional therapy settings. Research highlighted in the European Journal of Physical and Rehabilitation Medicine demonstrates the efficacy of internet-based home training programs in enhancing balance and postural control, comparable to conventional hippotherapy (Frevel & Mäurer, 2015). Similarly, the Upper Limb Training and Assessment (ULTrA) program significantly improved arm and hand coordination in adults with cerebral palsy, showing that targeted exercises delivered through digital platforms can effectively improve motor functions (Brown et al., 2010). Furthermore, hippotherapy simulation exercises for individuals with ankylosing spondylitis showed better improvement in disease activity indices compared to conventional home exercises, supporting the idea that simulated therapeutic interventions can offer comparable short-term benefits (Salbaş & Karahan, 2022).

These studies collectively reinforce the concept that HT-sim, by replicating the key physical and sensory experiences of traditional hippotherapy, presents a promising alternative for therapeutic intervention. The adaptability and accessibility of HT-sim make it a valuable tool in the therapeutic regime for neuromuscular patients with severe intellectual disabilities, aligning well with ongoing research. This convergence of evidence supports the hypothesis that HT-sim not only mimics traditional HT but may also enhance therapeutic accessibility and effectiveness, particularly in scenarios where conventional HT is not feasible.

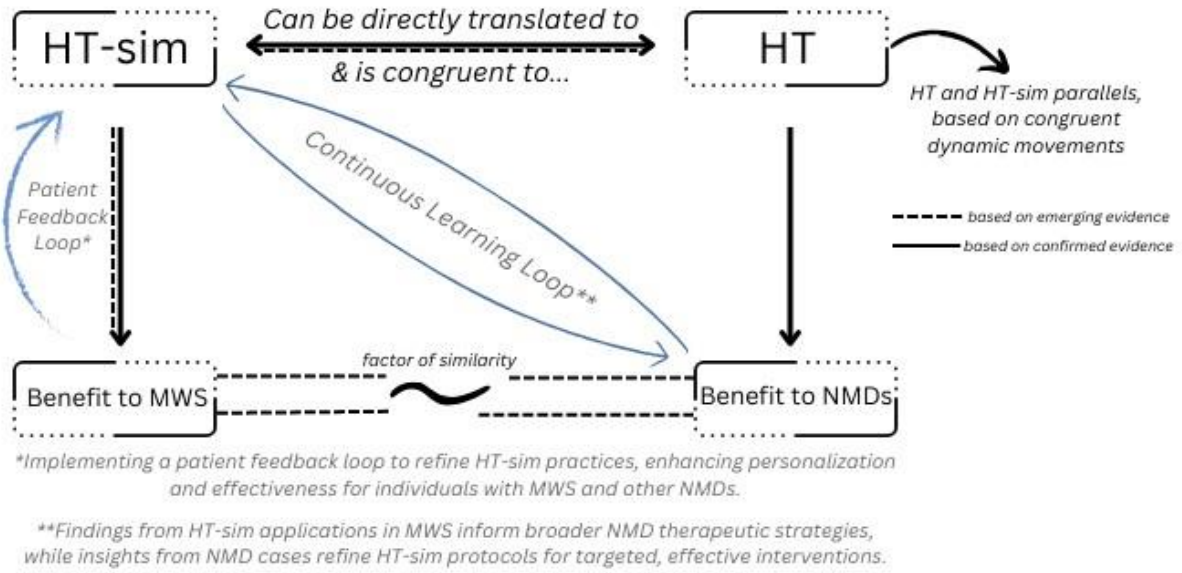

Figure 3: *Conceptual Framework for HT and HT-sim Integration:*
This model delineates the hypothesized translation of HT's benefits to HT-sim, demonstrating the congruence of therapeutic movements and the potential shared benefits for MWS and other neuromuscular disorders (NMDs). Solid lines represent established evidence of HT's efficacy for NMDs, while dashed lines indicate emerging evidence from HT-sim applications in MWS. The Patient Feedback and Continuous Learning Loops represent the iterative processes of personalizing and enhancing HT-sim based on patient outcomes and cross-condition learnings.

The framework depicted in Figure 3 serves as a foundational model, postulating that HT-sim could encompass the therapeutic essence of HT through congruent dynamic movements, adapted for use with an ESB and visual simulation. The Patient Feedback Loop underscores the significance of individual patient responses in refining the HT-sim approach, ensuring tailored interventions that resonate with each patient's needs and capabilities. Concurrently, the Continuous Learning Loop facilitates the cross-pollination of insights derived from HT-sim in MWS to the broader spectrum of NMDs, thereby enriching our understanding and enhancing the efficacy of interventions across various neuromuscular conditions. This bilateral knowledge exchange is central to the evolution of HT-sim as a comprehensive therapeutic modality.

In summary, the parallels drawn between HT-sim and traditional HT validate our approach and highlight innovative ways to enhance accessibility to effective rehabilitation strategies. As HTsim simulations are refined, they support patients in achieving significant improvements in mobility and overall quality of life.

F. CASE STUDY

Overview

This section presents a detailed case study of a 32-year-old male, a resident at ACR Homes, with Mowat-Wilson Syndrome (MWS), highlighting his progress with Hippotherapy (HT) and HT-

sim over one year. The focus is on observed benefits, statistical analysis, and qualitative testimonials from caregivers and staff.

Introduction of the Patient and the Case for Hippotherapy

This case study focuses on a 32-year-old male receiving services from ACR Homes, who was diagnosed with Mowat-Wilson Syndrome (MWS) and severe cognitive impairment. Our resident's medical history includes a stable seizure disorder, Crohn's disease, pyelonephritis, and cardiac issues such as aortic/pulmonary stenosis and a resolved ventricular septal defect (VSD). He was admitted to a community residential setting, at age 18 due to increasing health complexities, including hospitalization for seizures and severe Crohn's disease-related complications.

In December 2017, a significant decline in our resident's walking ability was observed, linked to possible SI joint inflammation. This decline prompted consideration of hippotherapy (HT) to enhance his mobility, gait, and balance. However, the COVID-19 pandemic abruptly halted these sessions, severely impacting his mobility and limiting him to pivot transfers.

Recognizing the importance of hippotherapy, the residential staff has remained committed to reintegrating this therapy into our resident's routine. Hippotherapy aligns with his passion for horseback riding and is seen as essential for maintaining mobility and improving quality of life.

Resident's Journey with Hippotherapy: A Case Study

Early Engagement and Subsequent Interruption:

Our resident's passion for horseback riding since 2003 highlights the psychological and social benefits derived from equine interaction. An X-ray in early 2018 necessitated a temporary suspension of hippotherapy due to compromised weight-bearing capabilities. During this period, he engaged in supplementary physical therapies under careful supervision to maintain safety and adaptability in managing MWS.

Pandemic-Related Cessation and Adaptations:

The COVID-19 pandemic led to the suspension of hippotherapy sessions, which impacted our resident's mobility. Despite these challenges, the care staff's dedicated efforts resulted in marked improvements in his mobility and weight-bearing capabilities during the hiatus. He and the staff remained committed to resuming hippotherapy, recognizing its critical role in enhancing mobility and overall well-being.

Impact of the Pandemic on Hippotherapy – Adapting to Unprecedented Times

Disruption and Mobility Challenges:

The pandemic-induced suspension of hippotherapy sessions presented significant mobility challenges for our resident, necessitating reliance on pivot transfers. Despite these limitations, he showed resilience by achieving independent rising with guided assistance.

Reaffirmation of Hippotherapy's Value:
The commitment to reintegrating hippotherapy into our resident's care plan underscores its value in maintaining physical capabilities and managing his condition. Hippotherapy has provided him with joy and improved his quality of life, even amidst global health crises.

Concluding Statement
Our resident's journey through hippotherapy, disrupted by health issues and the COVID-19 pandemic, illustrates the complex interplay between therapeutic interventions and external factors. The steadfast dedication to leveraging hippotherapy's benefits demonstrates its integral role in enhancing the well-being and mobility of individuals with neurological conditions. This case study highlights the adaptability and resilience required in therapeutic settings and underscores the enduring value of hippotherapy for patients with Mowat-Wilson Syndrome and similar conditions.

G. **METHODS on HT-sim application**

Methodology and Initial Outcomes of Hippotherapy Simulation (HT-sim) Intervention
The Hippotherapy simulation (HT-sim) project integrates a comprehensive approach to physical therapy (PT) for individuals with mobility and cognitive challenges. This section outlines the methods employed to track therapy outcomes, proactive staff participation, supplementary interventions, and the project's phased development and implementation.

Proactive Staff Participation in Delivering PT
The successful implementation of HT-sim relies heavily on staff involvement, characterized by:

- *Refinement of Implementation:* Staff input is crucial to refining and strengthening the HT-sim protocol through quality improvement initiatives and safety enforcement, ensuring patient safety and therapy effectiveness.
- *Positive Outcomes Noted*: Improvements in evaluating slip criteria, consistent monitoring of slips, therapy duration, patient engagement, and qualitative feedback to tailor PT to individual needs.
- *Challenges Encountered*: Addressing the physical demands of HT-sim on staff, achieving precise outcome measurements, managing varied experience levels among staff, and creating a controlled environment to maximize patient engagement. Strategies included exploring interactive methods and continually adapting therapeutic strategies.

Measures for PT Tracking
To ensure a robust assessment of the HT-sim's efficacy, several measures were established:

- *Number of Slips*: Deviations from the central axis of the ESB were quantified through a performance score ranging from 0.1 to 1.0, noting incompatible movements that could lead to slips.
- *Time Tolerated*: Duration (beyond 10 minutes) the resident engaged with the therapy, reflected in a tolerance score from 0.1 to 1.0.
- *Interest Score*: Categorized from "did not tolerate" to "engaged and positive," with an accompanying interest score (0.1-1.0), documentation of positive feedback sessions, and periods requiring redirection.
- *Independent Movements*: Focused on noting compatible movement periods, indicating active patient engagement and motor response.

In addition to routine implementation of HT-sim through staff, a weekly self-led video analysis was conducted, where a full set of metrics was analyzed to better quantify and measure progress from quarter-to-quarter (Table 1).

Metric	Definition	Purpose	Detection Method	Relevancy
Slips	Lateral/vertical movement off ball axis	Evaluate balance and stability	Visual by therapists or motion-sensitive equipment	Enhance safety and stability for real horseback riding challenges
Time Tolerated	Duration (9-15 mins) actively engaged on ball	Assess endurance and adaptability in therapy	Observing and recording active engagement time	Measures capacity for longer, more intense sessions mirroring real horseback riding
Interest Score	Quantifies enjoyment and engagement levels during PT	Assess enjoyment and personalize therapy	Tallying positive feedback and redirections	Gauges emotional response, crucial for motivation and positive therapy outcomes
Accordance Periods (ACC)	Moments when movements align with simulated dynamics	Evaluate synchronization with therapeutic inputs	Observing and assessing movement synchronization with ball	Indicates readiness for real horseback riding, assesses therapeutic progress

Metric	Definition	Purpose	Detection Method	Relevancy
Discordance Periods (DCC)	Deviations from ball's center axis indicating potential slips or discomfort	Identify signs of discomfort or balance issues	Observing deviations in posture disrupting ball alignment	Aids in adjusting therapy to enhance safety and effectiveness
Metric	**Definition**	**Purpose**	**Detection Method**	**Relevancy**
Self-Realignments (S-R)	Voluntary adjustments to regain center on the exercise ball after a slip	Assess ability to independently correct position and maintain balance	Noting efforts to adjust seating or stance to a stable position	Enhances self-correction skills vital for safety and effectiveness in real horseback riding
Metric	**Definition**	**Purpose**	**Detection Method**	**Relevancy**
Self-Realignments/Slips Ratio (SRS)	Ratio of self-realignments to slips	Evaluate effectiveness of balance correction	Calculate by dividing total S-R by total slips in a session	Assesses motor response efficiency, crucial for therapy and real horseback riding safety

Table 1: A metrics table providing a comprehensive framework for assessing the effectiveness and safety of HT-sim interventions, offering crucial insights into the individual's therapeutic progress and readiness for more advanced therapy settings.

Supplementary Interventions and Timeline

The HT-sim project's development and evaluation have unfolded over several key phases (Fig. 4):

- *Initial Exploration and Development (Oct 2022 - Nov 2022)*: Methods to improve mobility and gait were explored, leading to the development of staff guides for safe and effective PT practice.
- *Official Implementation and Enhancement (Dec 2022 - Jan 2023)*: Sensitive tracking measures were established, with the official launch of the PT intervention focusing on promoting independence and fostering mind-muscle synergy.
- *Model Creation and Comparative Analysis (Feb 2023 - July 2023)*: Emphasis on activities promoting independence led to the creation of a model comparing HT-sim with traditional HT, analyzing detailed posture changes from seated to standing positions.

Study Plan and Staff Onboarding (Oct 2023 - Dec 2023): A targeted study plan was initiated, including onboarding new staff and testing new simulators, with extensive training and collection of testimonials highlighting improvements in weight-bearing, strength, and mobility.

- *Screening (May 2024)*: Reviews of evaluation criteria were completed to prepare for an official screening to assess present readiness for pursuing HT as a long-term involvement.

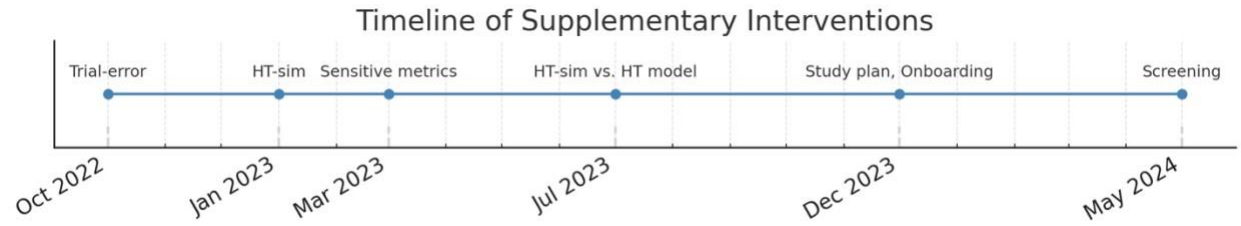

Figure 4: A longitudinal visual depicting the relevant developments in the HT-sim project, illustrating the progression from trial-and-error setups to the creation and officialization of HT-sim and the model with HT, followed by continued quality improvement and learning initiatives, concluding with the screening.

The phased approach underscores the comprehensive methodology of the HT-sim project, from initial development through implementation and ongoing evaluation. Through meticulous tracking of therapy outcomes and proactive staff participation, the HT-sim initiative aims to replicate the benefits of traditional hippotherapy within a simulated environment, offering promising prospects for enhancing patient well-being and mobility.

H. RESULTS, DISCUSSION, AND FUTURE OBJECTIVES of the Hippotherapy Simulation (HT-sim) Project

This section presents the preliminary results from the implementation of the Hippotherapy simulation (HT-sim) intervention, delineating the observed progress in our resident's mobility and engagement. Additionally, it encapsulates the evolution of the participant's abilities through therapy and outlines future objectives aimed at further enhancing therapeutic outcomes.

Preliminary Results

The HT-sim intervention yielded several notable outcomes over the course of the study:

- *Slip Frequency*: Initially, an increase in slip frequency was observed, attributed to the implementation of more sensitive measures for identifying slips. However, a significant decrease in slips was noted starting from Q2 onward, indicating improved stability and self-alignment by our resident.

Interest and Tolerance: There was a discernible improvement in our resident's interest and tolerance for the simulator over time. Although initial redirecting periods were inconclusive, overall engagement levels showed a positive trend.

- *Self-Alignments and Stability*: Measures such as composure while seated and events of readjustment indicated improvements in self-alignments and stability. Performance scores corroborated this positive trend.
- *Balance and Stance*: Our resident demonstrated improved balance and an ability to initiate movements independently, indicating enhanced motor control and stability.

Quantitative Analysis of Hippotherapy Simulation (HT-sim) Efficacy

This section delves into a comprehensive quantitative analysis of the effectiveness of the HT-sim intervention over five quarters (Q1-Q5), focusing on specific metrics: Self-Realignments (S-R), the S-R/Slips Ratio (SRS), and Accordance Periods (ACC). These metrics serve as critical indicators of the participant's motor control, reflex speed, and ability to synchronize movements with external stimuli.

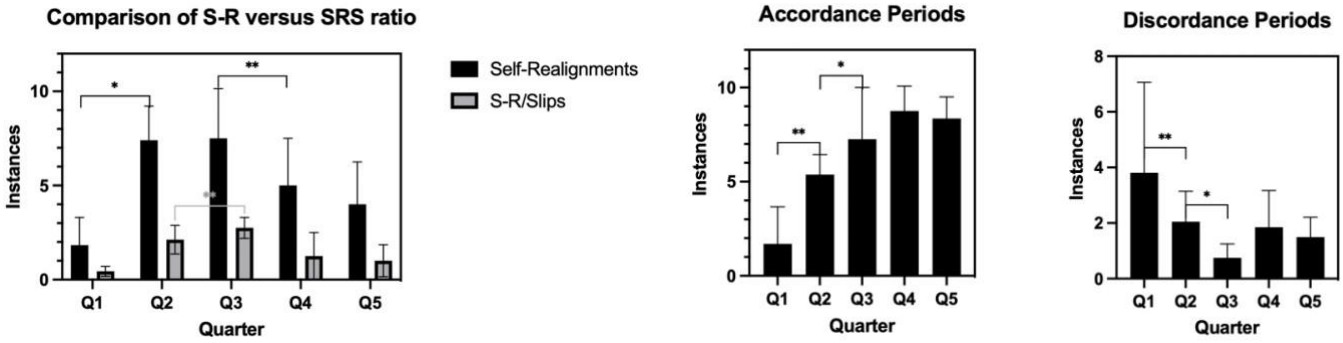

Figure 5. Graphs depicting our resident's progression throughout Q1 to Q5 of HT-sim, with the metrics of S-R and SRS (Fig. 5a), Accordance Periods (Fig. 5b), and Discordance Periods (Fig. 5c). * $P \leq 0.05$ | ** $P \leq 0.01$

Self-Realignments (S-R) and Slips: Evolution and Interpretation

The "Comparison of S-R versus SRS ratio" graph provides insights into the progression of our resident's motor control and stability during the HT-sim sessions.

- *Initial Acclimation Period (Q1-Q2)*: In the first quarter (Q1), our resident exhibited a low number of self-realignments and a high number of slips, indicative of initial acclimation to the HT-sim environment. This pattern persisted into the second quarter (Q2), with increased self-realignments but still high slips, marking the beginning stages of acclimation.
- *Growth in Motor Control (Q2-Q3)*: By the third quarter (Q3), there was a significant increase in self-realignments and a notable reduction in slips, demonstrating our resident's growing control and refined motor response. The S-R/slips ratio during this period highlighted his adaptation to the therapeutic interventions.

- *Mastery and Stability (Q4-Q5)*: In the final quarters (Q4 and Q5), minimal instances of both self-realignments and slips were observed, indicating our resident had reached an equilibrium. This suggests a level of mastery with the HT-sim, demonstrating an intuitive understanding of maintaining stability.

Accordance Periods (ACC): Evolution and Interpretation

- *ACC Metrics*: Showed a consistent increase over the study period, reflecting a linear improvement in our resident's ability to synchronize movements with external stimuli.
- *Initial Quarters (Q1)*: Our resident had relatively low accordance periods, indicating early challenges in harmonizing movements with the simulation.
- *Growth Period (Q2-Q4)*: Significant increases in accordance periods marked our resident's growing familiarity and control over the simulated environment. This trend continued into the third and fourth quarters, with a higher level of stabilized accordance periods.
- *Final Quarter (Q5)*: Our resident reached a plateau in accordance periods, suggesting intentional and stable motor control, underscoring HT-sim's value as a preparatory or supplementary intervention.

Discordance Periods (DCC): Evolution and Interpretation

- *DCC Metrics*: Showed a marked decrease over the study period, illustrating reduced instances of misaligned movements.
- *Initial Quarters (Q1)*: Our resident exhibited the highest number of discordance periods, highlighting initial motor control challenges.
- *Reduction Period (Q2-Q5)*: A significant reduction in discordance periods from Q2 onwards, with a stabilization in these periods over Q4 and Q5, indicated our resident's improved ability to adjust movements and reduce errors during the simulation.

Quantitative Analysis and Interpretation — Conclusion and Implications

The quantitative analysis reveals a clear trajectory of improvement in our resident's engagement with the HT-sim, marked by enhanced motor control, stability, and synchronization with external stimuli. The transition from frequent slips and fewer S-R to a mastery phase with minimal slips underscores a significant adaptation and learning curve. The steady increase in accordance periods highlights HT-sim's efficacy in mirroring traditional hippotherapy movements, supporting its potential as a viable preparatory or supplementary therapeutic intervention.

Overall, the results indicate that HT-sim not only helped our resident acclimate to the therapeutic environment but also enabled him to achieve near-mastery in maintaining stability, reflecting the program's success in enhancing neuromotor functions. This finding is crucial for informing future therapeutic strategies and underscores the value of HT-sim in neurorehabilitation for individuals with similar conditions.

The broader implications of these findings underscore the potential of HT-sim to serve as an accessible, safe, and effective therapeutic modality, especially for individuals with limited access to traditional hippotherapy.

Initial versus Lasting Impressions

The evolution of our resident's abilities through the course of the HT-sim therapy is marked by significant progress:

- *Beginning*: Initially, our resident struggled with weight-bearing on the ball, experiencing involuntary momentum leading to guaranteed slips.
- *Middle*: Over time, there was noticeable improvement in self-arising with support and self-balancing, indicating progression in motor skills and independence.
- *Lasting Impressions*: Presently, our resident has achieved a level of self-stabilization, enabling dynamic adjustments to prevent falls, thus demonstrating enhanced balance control.

These observations encapsulate our resident's therapeutic journey from initial challenges to achieving notable improvements in balance and mobility.

Testimonials:

- "While I worked with our resident mostly after the pandemic, I've noticed a significant improvement in his mobility. Walking and standing him up used to be daunting, but now, it's noticeably easier. He can bear his weight without risking slips or falls."
- "Working with our resident has taught me that he has much more agency in his movements than we perceive. He can semi-independently walk, self-arise with support, and navigate his environment with relative ease. His legs are activated on the ESB, demonstrating an intentional drive to stabilize."
- "I truly believe HT-sim has been helpful for our resident. It has made him more independent and motivated in terms of mobility, and he engages with staff more."
- Supervisor: "Our resident has enjoyed HT-sim and other new simulators. Each session seems enjoyable for him, helping him physically and mentally during the pandemic. He's moving better and engaging more with staff and others."
- Trainer/Therapist: "Our resident is able to balance well, though he needed significant adjusting onto the center of the horse's saddle during the final screening. While mounting/unmounting poses risks, his involvement in HT-sim has been fruitful in bringing him back to his baseline pre-mobility constraints."

These testimonials provide qualitative evidence of our resident's progress and support the quantitative data, illustrating the significant improvements in his mobility, stability, and overall engagement with the HT-sim intervention.

Future Objectives

The project's future objectives focus on both immediate and long-term goals:

- *Milestone in Mobility*: Assist our resident in reaching a new milestone in mobility, emphasizing independent movements, self-readjustments, and improved stability.
- *Reinstating Traditional Hippotherapy (HT)*: Explore opportunities for our resident to engage directly with horses and trainers, potentially through visits to the facility for enrichment activities, supported by parents/guardians.
- *Continued Evaluation of HT-sim*: Persist in utilizing and assessing the progress made through HT-sim as a supplementary therapeutic outlet.

The HT-sim project is conceptualized as a supplement to our resident's overall care plan, serving as a crucial stepping stone towards traditional hippotherapy. While HT-sim aids in preparing him for more substantial interventions, traditional HT remains integral for sustained mobility improvements and quality of life enhancements.

In summary, the HT-sim project represents a promising addition to therapeutic interventions for residents with mobility and cognitive challenges. Through detailed tracking of progress, thoughtful staff engagement, and strategic future planning, the project lays the groundwork for enhancing standard care and fostering greater independence and well-being for those in need.

I. Post-Assessment/Post-Evaluation/Follow-up Assessment

In May 2024, a crucial HT screening was organized to evaluate our resident's readiness for hippotherapy and to establish safety protocols. This screening at Hold Your Horses, a facility with an on-site hippotherapy-trained physical therapist, was made possible after overcoming several barriers, including limited waiver funds and pandemic-related restrictions. The primary goal was to gain comprehensive insights into his current capabilities and to refine future therapeutic approaches.

May 2024: HT Screening – Objectives & Methodology

Objectives:

- Establish safety guidelines and assess HT readiness.

Methodology:

- Observation of mounting ability, independent postural adjustments (IPAs), and control during trotting.
- Interaction with an on-site HT-trained physical therapist, for expert insights.

The primary objectives of the May 2024 HT screening were to establish safety guidelines and assess our resident's readiness for more formal evaluations. The methodology involved a comprehensive observation of his mounting ability, independent postural adjustments (IPAs), and control during trotting. Additionally, interaction with an on-site physical therapist provided expert insights.

The session aimed to establish safety protocols and assess our resident's readiness for more formal evaluations. The focus was on understanding the level of assistance he required to maintain balance and the challenges he faced with self-led IPAs. The physical therapist emphasized the need for compelling evidence regarding the benefits of hippotherapy, especially given the risks associated with self-led adjustments.

Comparisons & Findings:

- Performance While Trotting: Demonstrated strong core and pelvic control.
- Mounting Ability and Centering Challenges: Difficulty in achieving a centered position independently.
- Immediate Outcomes: Recommendations for non-riding OT sessions, despite the goal to continue horseback riding.

Our resident demonstrated a solid ability to keep up with horse-trotting due to his training on the exercise ball, showcasing strong pelvic control and core stability. However, his mounting technique revealed challenges. The physical therapist noted that his prompted IPAs needed more work, as staff provided significant assistance. The inability to center himself independently presents a major challenge and risk during unexpected horse movements.

It became evident that our resident required significant assistance (~75%) from staff to maintain a centered position on the horse. Self-led IPAs were identified as the biggest determinant, the lack of which, being a risk factor for continuing horseback riding. Although improving self-led IPAs could be a goal for the next evaluation, more convincing evidence of hippotherapy's potential benefits is necessary. This is particularly important given the potential risk of falls due to limitations in IPA and the limited extent of benefit in adult patients like our resident, where neural circuits and mind-muscle connectivity can only improve so much compared to pediatric patients.

The screening was crucial in establishing safety guidelines and evaluating our resident's baseline abilities, both motor and non-motor. This set the stage for future goals, which involve significant improvements in IPAs, achievable through consistent exercise, physical therapy (PT), and range of motion (ROM) activities. A follow-up meeting with supervisors, the care team, and guardians is required to discuss the next steps.

Post-Screening Considerations:

- Future Evaluations: Plan for enhanced training focused on improving IPAs.
- Coordination with Past Therapists: Reach out to previous therapists for insights and tailored recommendations.
- Continued Commitment: Engage in additional OT sessions such as grooming for holistic benefits.

Future evaluations will focus on enhancing our resident's ability to perform independent postural adjustments through targeted exercises like using a recumbent bike and consistent ROM/PT activities. Coordination with the physical therapist and reaching out to his former therapists for more personalized guidance will be crucial. Despite recommendations for alternative OT sessions, maintaining the focus on hippotherapy aligns with his and his family's long-term objectives, highlighting the need to balance immediate safety with long-term goals.

Planned Future Objectives/Actions – Exploring Paths Forward:

- Pursuing HT Sessions: Tailor interventions to improve IPAs, contingent on parental approval and feasible financing solutions.
- Enhance Occupational Therapy (OT) Sessions: Prioritize non-riding OT activities like grooming and feeding horses. Consider alternative animal interactions to enrich quality of life without the logistical and financial burdens of HT.
- Evaluate HT-sim as a Long-Term Solution: Focus on HT-sim to maintain therapeutic benefits in a cost-effective manner. Align with available resources and provide a sustainable conclusion, focusing on achievable outcomes with minimal risks.

Given the options, we are exploring three strategic paths for our resident's continued therapy post-screening:

1. HT Full Sessions: Assertively pursue HT with funding, parental support, and interventions for improvements.
2. OT-Focused Approach: Shift focus to OT activities like grooming and feeding, providing meaningful engagement with animals while sidestepping the higher demands and risks of HT. This is less optimal due to its deviation from direct therapeutic goals.
3. Prioritize HT-sim: Given the constraints around financing and logistics, continuing with HT-sim offers a practical compromise, sustaining therapeutic engagement and benefits in a financially and logistically manageable way. This option suits the immediate circumstances and allows the project to conclude effectively with transfer of leadership.

After discussions with our resident's guardians and considering the safety risks involved in emergency dismounts, the decision was made not to pursue actual horseback riding. Despite the possibility of improving IPAs and overall adjustments, the primary concern remains safety risks. This decision might differ for children, who are lighter and in a critical development phase,

where hippotherapy can significantly activate neural circuits and improve walking ability due to the horse's gait providing up to 100 inputs per second.

Instead, the care team plans to enable our resident to interact with horses in other ways, possibly through his parent's weekly horseback riding sessions. This approach offers a free and accessible way to start, addressing financial and accessibility constraints associated with facilities like Hold Your Horses.

Present Solution:

- Disengage from HT due to safety concerns and sustained finances.
- A combined solution focused on equine interactions via guardians, with HT-sim.
    - Safety & Finance Decision
    - Alternative Interactions
    - Continued HT-Sim Utilization
    - QI, Staff Opportunities

Given significant safety risks and financial concerns, discontinuing traditional HT is a practical decision. Our resident will continue interacting with horses through safer, guardian-facilitated activities, providing cost-effective therapy continuity. HT-sim will remain integral to his therapy, incorporating personalized experiences for ongoing therapeutic benefits and innovation opportunities for the care team.

J. **Takeaways of HT-sim Program**

The HT-sim program has achieved several significant milestones:

Accomplishments:

- Organized a screening at our resident's prior horse-riding facility, Hold Your Horses, which was previously impossible due to a lack of on-site hippotherapy-trained physical therapists and limited waiver funds.
- Continuously worked with our resident's case manager to secure necessary funding, overcoming financial barriers that currently make HT mostly out-of-pocket, with some support from waiver funds.

Key Insights and Outcomes:

- The recent screening at Hold Your Horses provided a comprehensive interaction with horses and therapists, giving clear insights into our resident's current capabilities and areas needing focused intervention.

- This screening highlighted the accessibility struggles of hippotherapy, especially for patients with higher needs like our resident. The ability to secure a screening only four years post-pandemic underscores the challenges in accessing these services.

Impact of HT-sim:

- HT-sim facilitated staff camaraderie, stronger interactions with our resident, and enhanced accountability measures, ensuring consistent implementation of HT-sim and other PT exercises.
- Improved tracking, communication, and adherence measures among staff were achieved, contributing to a more effective therapeutic environment.

Therapeutic Benefits:

- HT-sim's ability to mimic traditional HT and produce similar benefits at home was crucial during the pandemic when HT services were unavailable. This included improved mind-muscle connection, ROM, muscle strength, tone, flexibility, and increased independence.
- Despite 19 months, or approximately six quarters, of HT-sim not directly resulting in the final goal of restarting HT, the program provided significant physical and mental benefits, demonstrating its value as an alternative therapeutic modality.

Future Directions:

- Continued focus on HT-sim as a core component of our resident's therapy, enhancing it with personalized content such as POV experiences related to the guardian's interactions with horses.
- Ongoing quality improvement initiatives within the care team, encouraging innovation in therapeutic practices and providing staff with opportunities to develop new therapy modalities.
- Exploring alternative and cost-effective ways for our resident to interact with horses, maintaining the therapeutic engagement and benefits.

The HT-sim program has been instrumental in sustaining therapeutic progress for our resident, offering a viable alternative to traditional hippotherapy during challenging times. Its continued utilization and enhancement will remain a priority, ensuring that he receives consistent and effective therapy while exploring new opportunities for engagement and improvement.

Conclusion

HT-sim represents a significant step forward in addressing the challenges of accessibility, affordability, and safety in hippotherapy. By leveraging technology and innovative practices, it has the potential to transform the therapeutic landscape for individuals with neuromuscular and

neurological conditions. As we navigate the limitations and explore the possibilities, the role of advocacy, policy change, and technological advancement becomes increasingly important in ensuring that the benefits of hippotherapy are accessible to all who need them.

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Sources:

- Adam MP, Conta J, Bean LJH. Mowat-Wilson Syndrome. 2007 Mar 28 [Updated 2019 Jul 25]. In: Adam MP, Feldman J, Mirzaa GM, et al., editors. GeneReviews® [Internet]. Seattle (WA): University of Washington, Seattle; 1993-2024. Available from: https://www.ncbi.nlm.nih.gov/books/NBK1412/
- Bronson, C., Brewerton, K., Ong, J., Palanca, C., & Sullivan, S. J. (2010). Does hippotherapy improve balance in persons with multiple sclerosis: a systematic review. European journal of physical and rehabilitation medicine, 46(3), 347–353.
- Brown, S. H., Lewis, C. A., McCarthy, J. M., Doyle, S. T., & Hurvitz, E. A. (2010). The effects of Internet-based home training on upper limb function in adults with cerebral palsy. Neurorehabilitation and neural repair, 24(6), 575–583. https://doi.org/10.1177/1545968310361956
- Collado-Mateo, D., Lavín-Pérez, A. M., Fuentes García, J. P., GarcíaGordillo, M. Á., & Villafaina, S. (2020). Effects of Equine-Assisted Therapies or Horse-Riding Simulators on Chronic Pain: A Systematic Review and Meta-Analysis. *Medicina (Kaunas, Lithuania)*, *56*(9), 444. https://doi.org/10.3390/medicina56090444
- Debuse D, Gibb C, Chandler C. Effects of hippotherapy on people with cerebral palsy from the users' perspective: a qualitative study. Physiother Theory Pract. 2009;25(3):174192. doi:10.1080/09593980902776662
- Frevel, D., & Mäurer, M. (2015). Internet-based home training is capable to improve balance in multiple sclerosis: a randomized controlled trial. European journal of physical and rehabilitation medicine, 51(1), 23–30.
- Funakoshi, Ryota & Masuda, Koji & Uchiyama, Hidehiko & Ohta, Mitsuaki. (2018). A possible mechanism of horseback riding on dynamic trunk alignment. Heliyon. 4. e00777. 10.1016/j.heliyon.2018.e00777.
- He, L., Yu, K., Lu, F., Wang, J., Wu, L. N., Zhao, C., Li, Q., Zhou, X., Liu, H., Mu, D., Xin, M., Qiu, M., & Lu, Q. R. (2018). Transcriptional Regulator ZEB2 Is Essential for Bergmann Glia Development. The Journal of neuroscience : the official journal of the Society for Neuroscience, 38(6), 1575–1587. https://doi.org/10.1523/JNEUROSCI.2674-17.2018
- Herrero, P., Asensio, A., García, E., Marco, A., Oliván, B., Ibarz, A., GómezTrullén, E. M., & Casas, R. (2010). Study of the therapeutic effects of an advanced hippotherapy simulator in children with cerebral palsy: a randomised controlled trial. *BMC musculoskeletal disorders*, *11*, 71. https://doi.org/10.1186/1471-2474-11-71
- Hilliere, C., Collado-Mateo, D., Villafaina, S., Duque-Fonseca, P., & Parraça, J. A. (2018). Benefits of Hippotherapy and Horse Riding Simulation Exercise on Healthy Older Adults: A Systematic Review. *PM & R : the journal of injury, function, and rehabilitation*, *10*(10), 1062–1072. https://doi.org/10.1016/j.pmrj.2018.03.019

- Kim, S., Yuk, G. C., & Gak, H. (2013). Effects of the horse riding simulator and ball exercises on balance of the elderly. Journal of physical therapy science, 25(11), 1425–1428. https://doi.org/10.1589/jpts.25.1425
- Lee, C. W., Kim, S. G., & Na, S. S. (2014). The effects of hippotherapy and a horse riding simulator on the balance of children with cerebral palsy. *Journal of physical therapy science*, *26*(3), 423–425. https://doi.org/10.1589/jpts.26.423
- Quintes, S., Brinkmann, B. G., Ebert, M., Fröb, F., Kungl, T., Arlt, F. A., Tarabykin, V., Huylebroeck, D., Meijer, D., Suter, U., Wegner, M., Sereda, M. W., & Nave, K. A. (2016). Zeb2 is essential for Schwann cell differentiation, myelination and nerve repair. Nature neuroscience, 19(8), 1050–1059. https://doi.org/10.1038/nn.4321
- Salbaş, E., & Karahan, A. Y. (2022). Effects of hippotherapy simulation exercise vs. conventional home exercises on muscle strength and balance in people with multiple sclerosis: A randomized controlled trial. Multiple sclerosis and related disorders, 68, 104111. https://doi.org/10.1016/j.msard.2022.104111
- Schuster, J., Klar, J., Khalfallah, A., Laan, L., Hoeber, J., Fatima, A., Sequeira, V. M., Jin, Z., Korol, S. V., Huss, M., Nordgren, A., Anderlid, B. M., Gallant, C., Birnir, B., & Dahl, N. (2022). ZEB2 haploinsufficient Mowat-Wilson syndrome induced pluripotent stem cells show disrupted GABAergic transcriptional regulation and function. Frontiers in molecular neuroscience, 15, 988993. https://doi.org/10.3389/fnmol.2022.988993
- Uldahl M, Christensen JW, Clayton HM. Relationships between the Rider's Pelvic Mobility and Balance on a Gymnastic Ball with Equestrian Skills and Effects on Horse Welfare. Animals. 2021; 11(2):453. https://doi.org/10.3390/ani11020453
- Willgens, A.M., Erdman, E.A. (2019). Using Hippotherapy Strategies for Children and Youth with Cerebral Palsy. In: Miller, F., Bachrach, S., Lennon, N., O'Neil, M. (eds) Cerebral Palsy. Springer, Cham. https://doi.org/10.1007/978-3-319-50592-3_163-1