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IMPROVING MOTOR COORDINATION AND SOCIAL DEVELOPMENT IN CHILDREN WITH AUTISM THROUGH EQUINE ASSISTED THERAPY

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Abstract A study is conducted to evaluate the effects of equine-assisted therapy on children with autism, which focuses on motor coordination and social development. Motion capture analysis is applied. Significant improvements in stride length are observed in the riding group. As a result, better balance, posture, and movement are achieved. However, no comparable progress is observed in the non-riding group, although physical exercises are performed. Therefore, the observed effects are attributed to equine-assisted therapy rather than general physical activity. The pedagogical curriculum test of psychological and social skills evidenced significant gains in communication, self-care, occupation, and socialization for the riding group and no measurable changes for the non-riding group. These findings suggest that equine therapy has some remarkable rewards on motor and social development in children with autism, though further research is needed to confirm and expand upon these results.

Keywords: Hippotherapy, Autism, Equine Assisted Therapy, Children with Autism, Autism Spectrum Disorder, Motor Coordination, Social Development, Rehabilitation, Quality of Life, Applied Mathematics, Psychomotor Skills.

AMS Mathematics Subject Classification: 92C50, 62P10.

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1 Introduction

Autism Spectrum Disorder (ASD) is marked by difficulties in social interaction, communication, and repetitive behaviors [1]. In addition, many children with ASD experience deficits in motor coordination, which affect daily activities and reduce quality of life. Early intervention is therefore emphasized, because critical motor and social skills are developed at early ages [2]. For this reason, movement based therapies receive increased attention, because both motor and social domains are addressed. Equine assisted therapy (EAT) is identified as one such intervention [3]. EAT integrates physical activity, sensory input, and social engagement through horseback riding. The three dimensional movement of the horse is provided to the rider, by which motor and sensory systems are stimulated [4]. As a result, physical coordination is improved, and opportunities for communication and social interaction are created, which are commonly impaired in autism [5]. Therefore, EAT is regarded as a promising intervention for children with ASD. Research evidence shows that EAT improves motor skills, e.g., balance, coordination, strength, and posture, in children with ASD [6,7].

The structured horse related activities are associated with gains in motor proficiency, which suggests that common motor impairments are effectively addressed. Moreover, improvements in upper limb coordination and strength are reported, while hippotherapy, which represents a specific form of EAT, is associated with reduced postural sway and enhanced motor control and stability [5,8]. Besides motor benefits, positive effects on social abilities and adaptive behavior are reported. Improvements in social functioning, executive functioning, and communication

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skills are observed in children who receive EAT. Increased engagement with therapists and animals is encouraged, which supports social interaction and reduces social disconnection in individuals with ASD [9,10]. In addition, higher participation in daily activities, e.g., self care and social interaction, is reported, which indicates improved adaptive behavior and quality of life. EAT therefore represents a comprehensive approach, in which both motor and social challenges are addressed [11]. The consistent positive outcomes reported across studies suggest that EAT functions as an effective complementary therapy, which supports physical and social development. However, further large scale studies are required, because long term effects and sustainability of improvements require clarification [12]. In fact, EAT shows strong potential for enhancing quality of life in children with ASD, because key developmental domains are targeted and overall well being is supported [6,13].

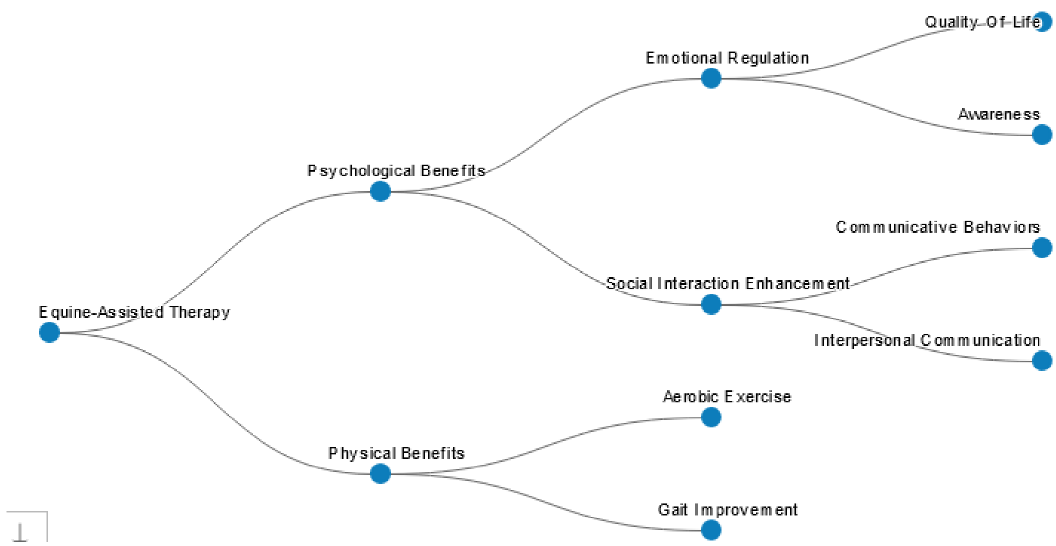

Figure 1: State of the art and taxonomy of literature on ASD and EAT

The core issues in autism are defined by disruptions in social cognitive and communication development, which affect personality structure and daily functioning. Autism Spectrum Disorder (ASD) includes multiple forms, which are grouped under a single syndrome and are defined as a genetic and neurodevelopmental disorder. Prevalence is estimated at approximately 0.5 percent of the population, with higher rates reported in boys and increasing diagnosis attributed to improved awareness and diagnostic methods. Autism presents with a wide range of intellectual abilities, i.e., from severe intellectual disability to normal or above average cognitive functioning, and co occurrence with other developmental disorders is frequently reported. Despite the absence of visible physical signs, diagnosis is often delayed, because recognition and understanding remain challenging. In fact, autism is defined as a developmental disorder rather than a mental illness, because typical developmental processes are disrupted [14]. The condition is non curable, and life expectancy is generally unaffected. However, difficulties in social inclusion and independent functioning are commonly observed. Therefore, early intervention is emphasized, because outcomes in communication and social skills are significantly improved. Clinical presentation is characterized by early onset, which is usually before 18 months, and includes impaired social reciprocity, communication deficits, and restricted or repetitive behaviors [15]. Symptom severity varies across individuals and may change over time. In children with higher cognitive abilities, interests are often narrowly focused on specific topics. While social and communication difficulties persist, symptom intensity may decrease with age. Progress is achievable for many individuals with autism, as long as early and appropriate intervention is provided [16]. Research on autism has expanded since the 1960s, after initial contributions from early investigators, and continues to evolve with the objective of improving diagnosis, care, and social inclusion. In this study, the effects of equine assisted therapy (EAT) on motor coordination and social development in children with autism are examined. ASD is regarded as a developmental condition that is associated with impairments in social interaction, communication, and behavior, which may result in lifelong disability. Severity varies widely, i.e., from profound impairment that requires lifelong care to milder forms that require individualized support [17]. Consequently, motion capture technology is applied to quantify stride length, which is used as an indicator of motor improvement. In addition, psychological and social abilities are assessed through a standardized pedagogical test. By comparison of children who participate in EAT with those who do not, the potential of this therapy to support both motor performance and social development in children with autism is demonstrated.

2 Methods

2.1 Study Overview and Hypothesis

This investigation is conducted in Hungary to examine the effects of hippotherapy (horse riding) on motor coordination in children with ASD. Initial observations are made at an auxiliary school, in which students receive hippotherapy. Significant improvements in motor coordination are observed. These findings are consistent with personal experience. Therefore, further examination is conducted to assess the effects of hippotherapy on motor skills, particularly walking, in children with ASD.Children diagnosed with ASD are randomly selected from a specific school in Budapest. Before the investigation, a medical examination is performed for each child, because suitability for participation is required. Walking is selected as the test movement, because it is a common and low-impact activity, which does not impose physical or psychological strain. It is hypothesized that improved motor coordination through hippotherapy results in measurable changes in walking ability.Walking is characterized by the coordination of multiple muscle groups, appropriate musculoskeletal development, and effective muscle regulation. Furthermore, proprioception is considered essential, because body position in space is determined through this function. For this reason, improved coordination through hippotherapy is expected to positively affect these components of walking.

2.2 Testing Tools: The Goethe Gait Lab Motion Testing System

The Goethe Gait Lab motion testing apparatus is applied to capture gait (Figure 2) [18]. Walking is recorded from four perspectives, i.e., front, back, left, and right. Four video cameras are employed for data acquisition. The recorded data is analyzed with APAS video analysis software in the Department of Biomechanics at the Hungarian University of Physical Education. Movement assessment is based on the Dempster model, which tracks body segments in detail. Accurate anthropometric measurements are obtained to determine the center points of body segments for three-dimensional analysis. Before data collection, calibration is performed to ensure measurement accuracy. A calibration body with eight marked points is placed in the testing area. After calibration, the calibration body is removed, because interference with movement must be avoided.Data collection is conducted in a school gym, which imposes spatial limitations. Therefore, calibration is simplified through a grid, which defines directions and maintains alignment. In addition, accuracy is verified through preliminary trial measurements. For gait assessment, a 200 cm floor section is selected. This section is marked by two thick black lines, which define the step cycle. The Key anatomical points are marked on the childrenвЂ™s bodies for motion tracking. A modified Dempster body model is applied, which includes 18 anatomical landmarks and connecting segments. The center of mass is calculated based on height, weight, and individual body proportions. For this reason, movement analysis is achieved with increased precision. Anthropometric data supports tracking accuracy. Further verification is achieved through initial trials. Thus, calibrated motion capture and grid-based simplification are applied for effective analysis within limited space.

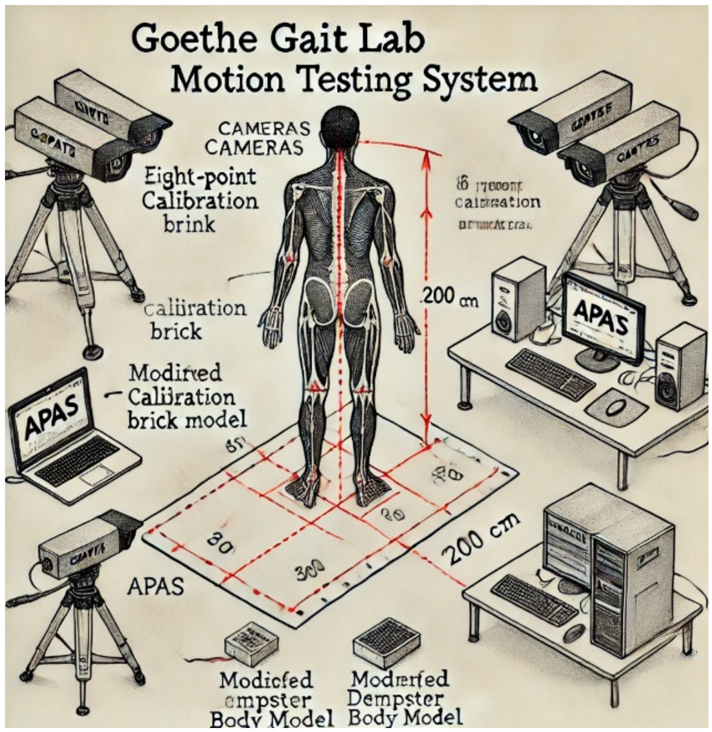

Figure 2: Schemtic representation of the concept (an AI illustration)

Calibration is completed before recordings begin, after accurate camera positioning. Because of the study location, a calibration procedure is required. Therefore, a calibration brick body with eight marked points is applied during testing. After the calibration position is fixed, the calibration body is removed, because interference with children movement must be avoided, while measurement positions remain unchanged. The coordinate of point 1 is not set to 0 in all three directions, because grid points must be defined relative to a virtual origin to ensure accurate data display. For example, coordinates are adjusted to prevent negative values (Figure 3). Thus, the eight points define the three spatial directions. Simplification of the control point configuration is required because of limited space in the school gym, in which motion capture is performed. Before data collection, measurement accuracy is verified through trial measurements.Two thick black lines are drawn on the floor to indicate a 200 cm section for gait analysis. This section defines the step cycle selected for processing (Figure 3). To track body movement, points of interest are marked on the body, and a body model is constructed. A modified Dempster body model is applied, which includes 18 anatomical landmarks connected by segments. In addition, a 19th point, which represents the center of mass, is calculated.Anthropometric data are recorded for each participant and incorporated into the analysis. Globally, parameters such as height and weight are included. Locally, the center of gravity for each body segment is determined based on measured values. For this reason, the body model is adjusted individually for each subject, thus precise movement analysis is achieved.

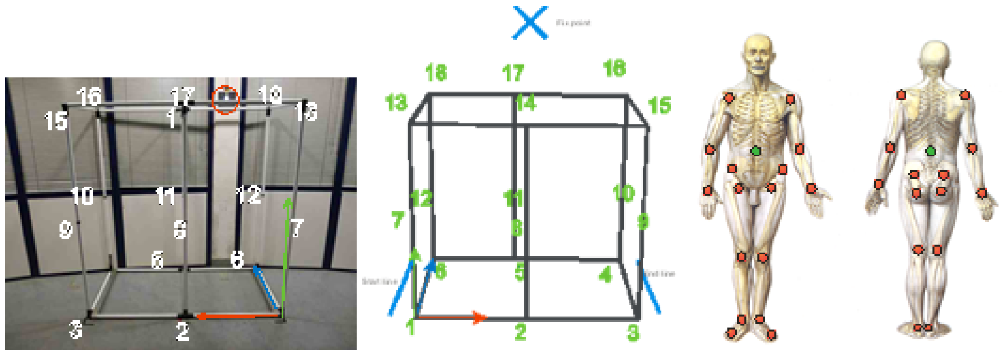

Figure 3: Validation, calibratuion and Body model

2.3 Group selection

Riding and non-riding children were randomly selected from among the children with autism in the particular school. The school doctor recommended that all children participate in therapeutic riding based on functional cervical scans.

Table 1: Group selection.

Criteria	**Therapy group**	**Control group**
Status	Autism	Autism
Age (years)	10–13	10–13
Number	13	13
Therapy	Horse riding therapy in Western style	Special exercises: fizioball; felülés; bordásfalon lábemelés.
Period	One month	One month

3 Results

3.1 Evaluation of the measurement: the gait-cycle analysis

To analyze the results, motor coordination data are compared between children who participate in equine-assisted therapy and those who do not. Data from 13 children in each group are included in the analysis, because two children from each group are unable to participate in the second assessment due to illness. The primary focus is placed on stride length, which is a key parameter for progress evaluation.A longer stride length is associated with faster movement, improved balance, and better coordination. Asymmetry between the two body sides is commonly observed in children with autism. One side, i.e., the right side, is often weaker. Therefore, stride length is selected to assess motor coordination. Stride length is defined as the distance from the initial ground contact of a foot to the subsequent ground contact of the same foot. For example, the stride length of the right foot is measured from the first ground contact of the right foot to the next contact of the same foot. Measurements are expressed in centimeters. Tracking accuracy is ensured through application of a body model, which identifies these points precisely. Stride length data are collected at two time points, i.e., before therapy and one month after therapy onset.

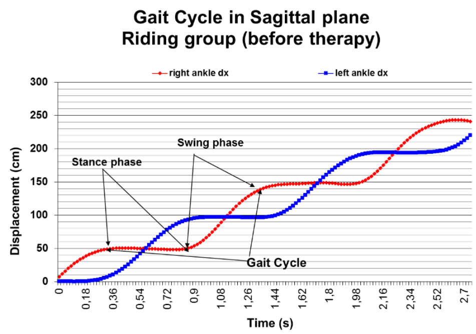

Figure 4: Footsteps of the riding child before therapy (sagittal direction)

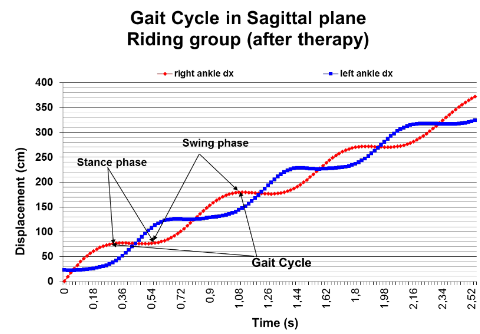

Figure 5: Pedometric image of the riding child after therapy

These measurements were taken for both the riding and non-riding groups. The data was analyzed by calculating the mean, standard deviation, and variance for each group. To determine the statistical significance of the differences between the groups, a paired t-test ($p<0.05$) was applied separately to both the right and left sides, allowing us to assess changes in motor coordination over time shown in Figure 6.

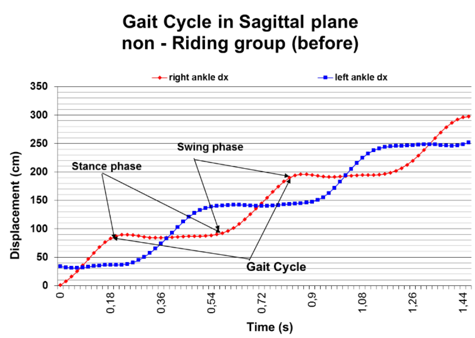

Figure 6: Step picture of the non-riding child before therapy

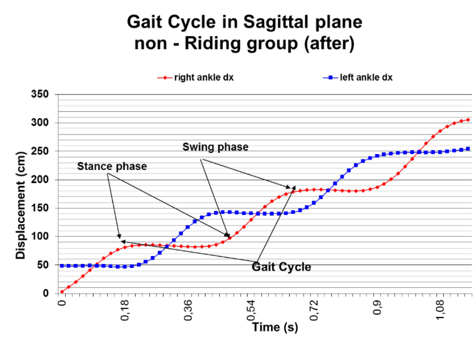

Figure 7: Steps of the non-riding child after therapy

For the children in the riding group, there was a significant increase in stride length on both the right and left sides, indicating substantial improvements in motor coordination and a reduction in hip movement asymmetry shown in Figure 8. Although the differences in the mean, standard deviation, and variance values appear quite large, it is important to consider that many children initially had a stride length around 13 cm at the first measurement. By contrast, a stride length of 50 cm is considered typical in the second measurement. This marked improvement underscores the positive effects of equine-assisted therapy on motor coordination and highlights the progress made in reducing asymmetry in movement.

In contrast, children in the non-riding group showed a significant decrease in stride length in the right leg (double T-test) but not in the left leg. Consider the following Figures 8-13. This is because the two sides of the children are not equally affected by gymnastics, and the asymmetry is very much preserved. However, there is a decrease on both sides compared to the original condition. Here again, the statistical values are relatively large due to the sample's heterogeneity and the magnitude of the change.

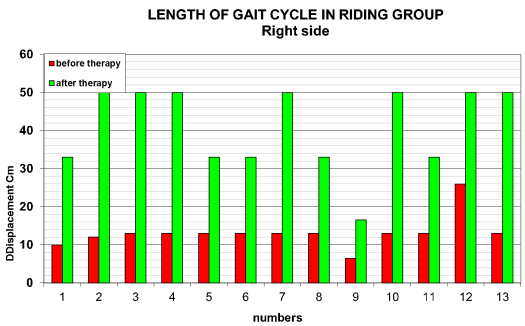

Figure 8: Step image of riding children on the right after one month

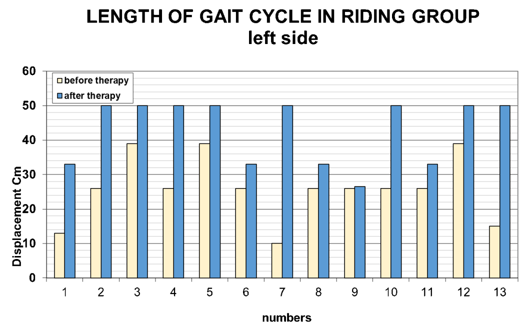

Figure 9: Step image of riding children on the left after one month

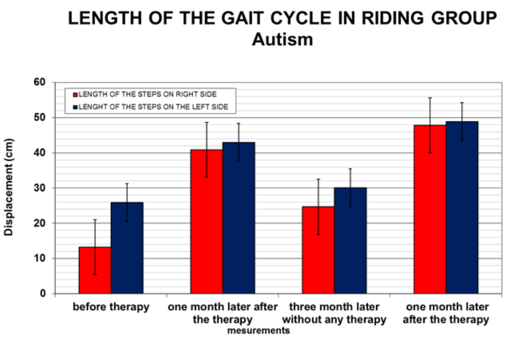

Figure 10: Steps of the riding group, right and left, before and after therapy

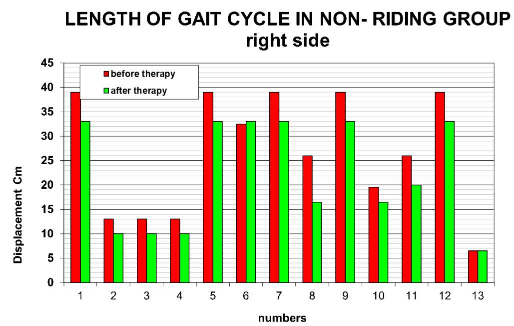

Figure 11: Step image of non-riding children on the right after one month

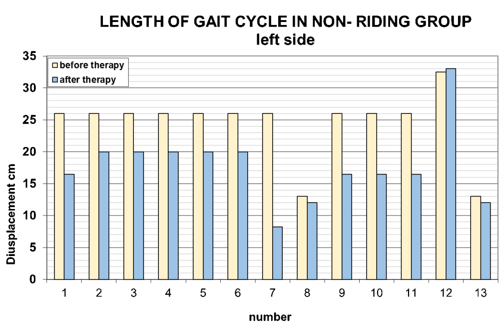

Figure 12: Step image of non-riding children on the left after one month

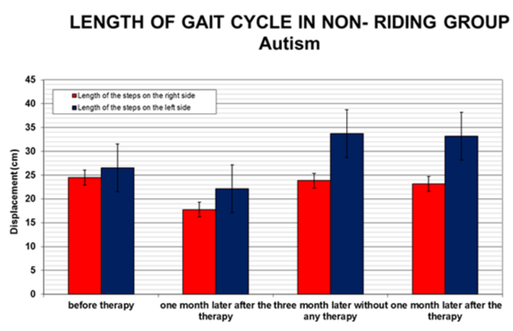

Figure 13: Step diagram of the riding group on the right and left before and after therapy

3.2 The Pedagogical Analysis and Curriculum, aka, PAC test

Examining psychological factors is crucial in understanding the overall development of children, which led us to use the Pedagogical Analysis and Curriculum (PAC) test, designed for children with mild to severe intellectual impairments. The PAC test assigns a score to each task based on whether the child can successfully complete it, providing a clear and visual representation of the childвЂ™s abilities. This approach allows for the tracking of developmental progress over time and helps identify specific areas where support may be needed. As a result, the PAC test serves as a valuable tool for educators and parents, offering insights into the child strengths and areas for growth, which can guide further educational and developmental interventions. This test assesses psychological and social skills across four key areas: Communication (including language, discrimination, number sense, and activities involving paper) Self service (tasks such as dressing, washing, transportation, and eating) Occupation (including large movements and finger dexterity) Socialization (tasks like housework and play). Each area is scored based on task completion by the child. Results are presented visually in a pie chart. This visualization is used to support parental interpretation of child progress. Furthermore, for comprehensive evaluation, scores from each domain are summed and averaged within each main category for both the riding and non-riding groups. A notable outcome is identified through this analysis. While identical remedial therapy is provided to both groups, statistically significant improvements are observed across all four domains, i.e., communication, self-help, occupation, and socialization, in the riding group. However, no statistically significant change is observed in the non-riding group during the one-year study period, despite equivalent therapy exposure. It is important to note that absence of statistical significance in the non-riding group does not exclude minor positive changes in pedagogical terms. Such changes may occur but remain undetected through quantitative analysis alone. Therefore, limitations of purely numerical assessment are acknowledged. In fact, the riding group shows clear advancement across all measured domains after therapy. The greatest improvement is observed in socialisation. This is followed by Self-service and Communication. Occupation also shows marked progress. Thus, the therapeutic intervention is associated with positive effects on social skills, autonomy, and communication. These outcomes are illustrated in Figure 14 and 15. However, improvement is more clearly demonstrated through a childвЂ™s drawing produced before and after one month of riding therapy

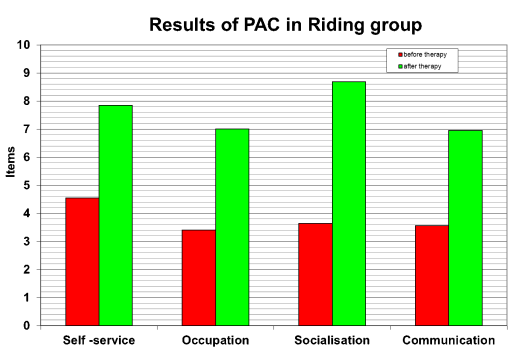

Figure 14: PAC test results in the riding group before/after therapy

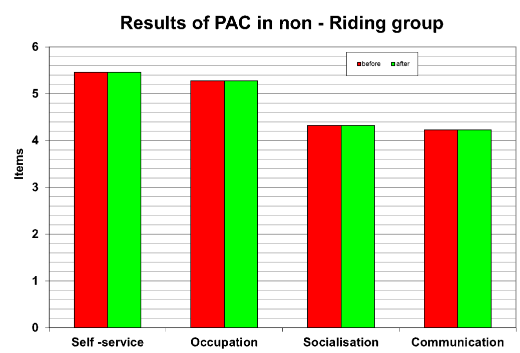

Figure 15: PAC test results in the non-riding group before/after therapy

4 Discussions

The results indicate that hippotherapy significantly improves motor coordination and social skills in children with autism. Gait cycle analysis shows a significant increase in stride length in both right and left lower extremities in the riding group. Therefore, improved balance and coordination are indicated. In addition, reduced asymmetry of hip movement is observed.However, the non-riding group shows a decrease in right-side stride length. On the left side, no significant change is detected. Thus, persistent asymmetry is indicated, and no improvement is observed, despite participation in general physical exercises. Variance and standard deviation differences, particularly within the riding group, highlight individual variability. Moreover, these differences emphasize the benefit of hippotherapy.Beyond physical outcomes, psychological and social effects are identified through the Pedagogical Analysis and Curriculum (PAC) test. Significant progress is recorded in communication, self-help, occupation, and socialization in the riding group. Such progress is not observed in the non-riding group. Furthermore, improvements in motor coordination are proportional to psychological and social gains. For this reason, holistic development is supported through hippotherapy.The therapy addresses physical and interpersonal difficulties simultaneously. Thus, comprehensive intervention is achieved. However, replication of these findings is required, along with evaluation of long-term effects. Larger samples and extended exposure are expected to provide broader insight and expanded application in therapeutic and educational contexts.The conclusions are supported by comparison of motion capture data between riding and non-riding groups. The most evident effects are observed in step length, posture, and movement. Riding therapy produces a marked increase in step length. As a result, balance improvement and movement progression are achieved. Such changes are not identified in the non-riding group, although physical exercises are provided. Moreover, PAC test outcomes are evaluated across four domains, i.e., self-service, occupation, socialization, and communication. All domains show significant positive change in the riding group. No change is detected in the non-riding group. Therefore, enhancement of physical and social skills in persons with autism is confirmed. Social development represents a primary therapeutic objective in autism. For this reason, benefits derived from hippotherapy are of particular importance. While the findings appear promising, confirmation through future studies is required. Further research is expected to clarify therapeutic mechanisms and refine application in both therapeutic and educational settings.

5 Conclusions

The study assesses the impact of EAT on motor coordination and social development in children with autism. Improvements in movement and interaction skills are observed among participants. Therefore, potential benefits for overall development are indicated. The results suggest that motor coordination and social skills are improved through EAT. Motion capture analysis shows marked increases in stride length, balance, and posture in the riding group. Thus, effectiveness for motor challenges is confirmed. Furthermore, PAC test outcomes indicate noticeable gains in communication, self-care, occupation, and socialization. Hence, broader psychological and social effects of the therapy are identified.These findings support the view that EAT represents a promising intervention for children with autism, because a combined focus on physical and social development is provided. However, confirmation of these findings and evaluation of long-term effects are required. Larger sample sizes and extended study durations are expected to yield more robust data. As a result, inclusion of EAT in therapeutic and educational programs is supported. Further research is expected to establish EAT within a multidisciplinary approach for improvement of overall well-being in children with autism.

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