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Research Article

Does Multidisciplinary and Intense Rehabilitation in a Post-Acute Brain Injury School Produce Positive Outcomes?

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Abstract

Introduction: The effectiveness of multidisciplinary rehabilitation has been shown to improve functional outcomes in adults with acquired brain injury. Late onset rehabilitation has shown improved gains in functional mobility for both adults and children. No study has examined the effects of increased multidisciplinary therapeutic intensity in a school setting for children post brain injury. With the evidence-based support of high intensity intervention and interdisciplinary support for children with brain injury, we hypothesized that increased post acute rehabilitation in an academic setting can improve mobility, communication, cognitive functioning, and health based outcomes.

Methods: Retrospective study of students pre- and post- first (2013-14) and second year (2014-15) of enrollment. Outcome measures: Cortical Visual Impairment (CVI) Ranges, Preschool Language Scale-5 (PLS), Brigance Inventory of Early Development III, Attendance Records, Health Records, Related service mandates and frequency, Pediatric Evaluation of Disability Inventory (PEDI) scores. Exclusion criteria: 1) No longer an enrolled student; 2) Part time student enrollment 3)Orthopedic surgery requiring extended hospitalization.

Results: There was a statistically ($p < 0.05$) significant improvement in the CVI range for the students receiving increased intervention in the academic setting. There was a significant improvement ($p<0.05$) in Social Functioning Domain as recorded on the PEDI that correlates with the improvement in overall communication performance as indicated by the PLS and Brigance assessments.

Conclusion: Due to the multifaceted nature of the program it is difficult to substantiate that improvements were directly related to one disciplines' intervention. Nonetheless intense rehabilitation in the school setting produced positive outcomes for children with severe disabilities due to brain injury. Further research is needed for implementation of post acute long--term rehabilitation and to interpret the improvements of function as it relates to the developing brain in children post brain injury.

Keywords: Brain injury; Children; High intensity intervention; Multidisciplinary rehabilitation; School-based services

Introduction

Brain injury has a high rate of incidence among children and can cause severe, global effects on a child's development and quality of life. Better understanding of effective long-term treatment for children with brain injury is an area of great need for further research and advancement. Due to the availability of therapy services in a school setting, the educational environment is a natural fit for addressing the needs of children with brain injuries [1]. In addition, a center-based approach facilitates the collaboration and integration of therapeutic interventions maximizing impact with a multidisciplinary approach. Multidisciplinary rehabilitation has been shown to effectively improve functional outcomes in adults with Acquired Brain Injury [2]. Late-onset rehabilitation has shown improved gains in functional mobility for both adults and children [3,4]. No study has examined the effects of increased multidisciplinary therapeutic intensity in a school setting for children with brain injury. With the evidence-based [5-9], support of high-intensity intervention and interdisciplinary support for children with brain injury, we hypothesize that intensive multidisciplinary post-acute rehabilitation within a school setting can improve mobility, communication, visual processing, cognitive functioning, and health-based outcomes.

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Background

Acquired Brain Injury (ABI), results in long standing limitations of activity and overall participation, unpredictable evolution of needs over time, and developmental transitions. These difficulties are still evident into adulthood [6,10,11]. Therefore, it is necessary to provide long term follow up services to reduce ongoing difficulties and prevent further complications [12,13]. Integrated multidisciplinary and long-term care must be initiated as early as possible post brain injury [14]. After children with long-term brain injury participate in rehabilitation and hospitalizations, they are often discharged to community programs. The intensity of therapeutic interventions diminish in

such settings due to lack of government funding and family time or resources.

Multidisciplinary approach

National Medical Policy [15], considers up to 3 hours per week of individualized, neuro-cognitive rehabilitation for diagnosed cognitive impairment after TBI necessary when it is a component of a multidisciplinary rehabilitation program consisting of at least 2 different types of therapies (e.g. physical therapy, occupational therapy, speech therapy).

Due to the evidence based support of high intensity intervention for children with brain injury, the model for multidisciplinary treatment in a private school setting was evaluated and how increased post acute rehabilitation in an academic setting can improve mobility, communication, cognitive functioning, health based outcomes and cortical visual impairment ranges. When appropriate visual accommodations are consistently implemented in daily routines and activities, the area of the brain that is processing vision is more consistently utilized and developed. Since vision is potentially embedded in all daily routines, it is important for all team members, therapists, educators and parents to collaborate when designing and implementing modifications and interventions [16].

Long-term studies of children and adolescents with TBI indicate initial recovery curves to decline or plateau with age (as compared to the with functioning of typically developing peers) [17-19]. This is significant because typically developing children continue to progress towards elevated cognitive, physical and behavioral goals, however students with brain injury decline without prolonged academic and therapeutic intervention.To measure the outcomes and changes in motor and social function, vision, communication and academics that occur in a high-intensity post acute multidisciplinary setting, the PEDI, CVI scale, PLS and Brigance III, and teacher observation were utilized, respectively. The rationale for using such assessments have been substantiated by evidence based practice [2,7,20-23].

Implications for Brain Injury School

In 2000 The Center for Disease Control [24], magnified the discrepancies of care for children with brain disorders. Specifically the CDC revealed "Parents and advocates report that appropriate services for children and youth with TBI are lacking." The CDC identified eight barriers to appropriate treatment of brain based disorders, one of which was as follows:

"Lack of appropriate educational services: the Individualized Educational Plan (IEP) does not meet the child/youth's need, or schools may tend to identify conditions they know how to manage. Research is needed to determine whether classifying children as having a TBI affects how they are managed in school."

Due to the lack of evidence and support for intensive resources for children with brain based disorder a private special education school was founded with the premise to establish a standard of post-acute intensive rehab model for aging children with brain injury. There is a range of functional outcomes as a result of early brain insult, with unknown prognostic markers due to neuroplasticity. Anderson et al., identifies these outcomes as representative of a "recovery continuum" depending on injury factors (severity, nature, age) and environmental influences (family, sociodemographic factors, interventions) [25]. The Individuals with Disability Education Act (IDEA) of 1997 required the school setting to address the needs of children with disabilities including related service intervention: PT, OT, Speech, Counseling, Vision and/or Hearing services. Therefore intensive therapeutic intervention for children with brain injury can foster changes throughout the recovery continuum as a result of government subsidized related service implementation through the education system.

The program model: Post Acute Brain Injury Private Special Education School

Academic department: The school's educational program focuses on the development of academic, cognitive and social skills aligned with each student's Individualized Education Plan (IEP) and is tailored to the very specific needs and capabilities of each student.All skills and strategies are taught through Direct Instruction, which research has shown to be one of the most promising approaches for teaching academic skills to students with TBI [26].The design and presentation features of the Direct Instruction approach specifically address many of the learning characteristics typical of students with TBI, including but not limited to problems with concentration, memory, organization and planning, thinking and reasoning, and generalization. Some of the features of the approach include breaking instructional tasks down into components, maintaining student engagement through high response and success rates, sufficient practice and review, sequencing skills, and incorporating generalizable strategies [27].

Teachers at the school strategically incorporate Direct Instruction methods into daily instruction while working one-on-one with students in 30-minute sessions throughout the school day.Methods and materials used to instruct students are individualized based on student need and the setting is controlled for visual and/or sound distractors to increase student focus and engagement. Teachers also create schedules to incorporate skills and input from each student's individual therapeutic goals and interventions, including implementation of sensory diets, integration of AAC devices and use of adaptive equipment into classroom activities.Progress on IEP goals is tracked on a consistent basis through teacher-created data collection measures to ensure student learning and is reported quarterly.

Conductive education: Conductive Education (CE) was founded in the 1940s by the Hungarian physician professor, Andras Peto. CE uses a psycho-educational approach that focuses primarily onintegrating the brain's ability to change and learn (neuroplasticity), the child's personality and lifestyle, and physiological and medical characteristics. CE approaches physical disabilities from an educational rather than a medical or paramedical perspective. The approach focuses on improving the physical effects of the disability, while encouraging motivation and active physical participation, to help students become independent and improve their self-esteem. The desired outcome

is to internalize the intended movement and achieve maximum independence, called orthofunction.

The Key Elements of CE include a CE Teacher (Conductor), CE Program, task series, daily routine, rhythmical intention, group setting, facilitation, as well as CE furniture and equipment. This intensive, multi-disciplinary holistic approach to education is designed for individuals with cerebral palsy, brain injury, spina bifida, and other motor challenges. The goal of CE is to improve quality of life, as well as the psychological well-being of the child and family.

The school provides the only CE program in New York State. Currently two staffed Conductor-Teachers work at the school in both group and individual sessions. During the 2013-14 and 2014-15 school years, students received CE at a frequency of 2 to 5 hours per week.

Vision education: The vision education program at the school focuses on each student's individual needs. Research shows that even though visual processing centers of the brain are damaged, new areas of the brain that are normally not responsible for visual processing can take over. The vision education team trains the entire staff how to work with students with Cortical Vision Impairment. They also collaborate with ophthalmologists and parents on a regular and consistent basis.

Cortical Visual Impairment (CVI) is defined as visual impairment due to brain damage [23]. With appropriate interventions and modifications, students with CVI will improve their visual processing abilities [23]. The vision education department usesthe CVI scale and observations in multiple settings to assess students' gains in functional vision.

With 21 students receiving vision services, no two students receive the same instruction or intervention plan. Students' individualized programs are based on their interests, functional tasks that they engage in on a daily basis, and personal visual preferences (color, visual field, processing time, maximum distance, etc.). Students receive direct instruction that combines push-in and pull-out services. During pull-out sessions, students work on specific visual skills. Some students with more significant manifestations of CVI work on building visual attention.They work on consistently looking at objects of a specific size, color, or visual appearance. These students often bring in their favorite items from home,because familiar items are generally more visually engaging for these students. Newcomb [7], supports the reliability of the CVI Range, the strategies and interventions based on the range, and an interdisciplinary collaborative approach that is used at a private special education school when visual accommodations, modifications, and techniques are integrated throughout the student's day.

Students in Phase II of CVI work on incorporating vision into functional tasks and daily routines. Some students at this level are working on looking at their spoons as they engage in feeding. They also work on looking at shiny targets as they turn the corner while walking in their gait trainers. Some students practice daily routines of looking and reaching for their iPod to put it into their backpack prior to dismissal. The collaborative sessions for students in Phase II focus on integrating visual strategies into academic sessions. The Vision Education Teachers model how, where, and what to present to students in order maximize their academic success and level of visual engagement in their other therapies.

Students in Phase III of CVI work on using vision as a means for learning. These students work on identifying photographs of familiar people throughout their daily routines and identifying photographs of simple landmarks in their daily routines in order to more effectively navigate the hallways. These students also have self-contained vision sessions in which they work on explicitly learning what makes one object or image different from another. In all cases, students benefit from push-in and pull-out services that are collaborative and highly individualized.

Christine Roman-Lantzy's reference entitled Cortical Visual Impairment [23], Second Editionwas published in 2018. The information in the second edition provides refined and updated explanations on the scoring process of CVI range. The scores and information in this paper are based on the information available in 2015.

Occupational Therapy: The occupational therapy department at the school places occupation at the core of all interventions, program design, evaluation, and interactions with students. Based on existing literature, neuroplasticity occurs at the greatest rate and frequency while individuals are engaged in meaningful occupations [28]. As a result of their diagnosis of traumatic and acquired brain injuries, students have vision, hearing, speech, and motoric limitations. These client factors can prevent students from engaging fully in desired occupations [29]. The occupational therapy department works to remediate these client factors through evidence-based hands-on treatment, as well as thorough use of adaptive methods and equipment.

Individualized care begins by addressing student occupational needs during interviews with potential students and parents to determine student preferences and preferred occupations to create a well-rounded strengths-based occupational profile. The occupational therapy department currently uses strength-based standardized measures and the sensory profile to build upon student strengths while also addressing deficits.

Following evaluation, services are provided to allow students to participate in classroom activities and community-based instruction using a model that supports both push-in and pull-out services. Occupational therapy services are provided on an intensive basis (generally 3 to 5 times per week for 60 minutes) based on therapist evaluation of student needs and existing research supporting the effectiveness of massed practice to promote neuroplasticity [28]. The occupational therapy gym includes equipment such as mats, therapy balls, mirrors, therapy benches, sensory integration equipment, adjustable lighting, and fine motor games and toys. During a given intervention session, a therapist may complete a variety of preparatory methods (sensory based, range of motion, gross motor play, etc.) to allow students to more fully engage in personally meaningful occupations throughout the session.

Occupation is incorporated throughout intervention sessions by allowing students opportunities for choice making; use of creative occupations such as art, cooking, and preferred music; and adapting preferred toys and games to meet therapeutic goals. During occupational therapy sessions, students are engaged in activities that not only address IEP goals, but also support functioning outside of the school environment by working on both activities of daily living and instrumental activities of daily living. Occupational therapy works closely with speech therapy to determine best communication access, because these students are non-verbal. This approach in turn allows therapists to have students engage in self-determination of goals and therapeutic sessions as much as possible.

Physical Therapy: The physical therapy (PT) program uses a functional goal-oriented therapy regimen based on the student's current level of progress. The program usesprinciples of Neuro-Developmental Treatment (NDT), which encourages critical therapeutic thinking and hands-on facilitation of desired musculature during the child-initiated movement to educate the child on how to create movement patterns in order to achieve a motivational and functional task. NDT has been shown to be successful in the treatment of children with neuromuscular impairment [30]. The PT department follows the American Physical Therapy Association's Published Guidelines for Physical Therapy Practice [31], when selecting intervention. As it states:

"Decisions about the interventions selected are based on the physical therapist's assessment of the individual's current condition and are contingent on the timely monitoring of the individual's response and the progress made toward achieving the goals. In prescribing interventions for an individual, the physical therapist includes parameters for each intervention (e.g., method, mode, or device; intensity, load, or tempo; duration and frequency; progression). Physical therapist intervention is focused on optimizing functional independence, emphasizes patient or client instruction, and promotes proactive, wellness-oriented lifestyles. Through appropriate education and instruction, the individual is encouraged to develop habits that will maintain or improve function; prevent recurrence of problems; and promote health, wellness, and fitness." (Guideline to Physical Therapy Practice 3rd Edition)

Physical therapeutic frequency for students was designated based on the significant amount of gross motor delay observed and evidenced by formal evaluation. Each of the students included in this study at the school received either 4 or 5 sessions a week for 60 minutes. Each student was assessed for quantitative measures to assess functional capabilities and clinical measurement. The physical therapy department utilized push-in/pull-out services and worked to make gains in these areas during the school year.

Intervention occurs in and out of the classroom, PT gym, school hallways, and neighboring community playgrounds and sidewalks. The gym has mirrors, mats, therapeutic balls, and play equipment for the children. Intervention is individualized and guided by the goals set by the IEP and the child's current physical therapist based on evaluation. All of the physical therapeutic intervention during the school year of 2013-2014 was conducted by one physical therapist.

Adjunct programs are additional therapeutic interventions to help with stretching, strengthening, and weight-bearing for improved endurance and function. Adjunct programs include (but are not limited to) aquatic therapy (which was not initiated during 2013-2014 and 2014-2015 school years), standing, walking, prone lying, sidelying, and biking. Physical therapy interventions are classified as follows per the Guidelines to Physical Therapy Practice: Patient or Client Instruction; Airway Clearance Techniques; Assistive Technology: Prescription, Application, and, as appropriate, Fabrication or Modification; Biophysical Agents; Functional Training in Self-Care and in Domestic, Education, Work, Community, Social, and Civic Life; Integumentary Repair and Protection Techniques; Manual Therapy Techniques; Motor Function Training; and Therapeutic Exercise. (Guidelines to PT Practice 3rd Edition).

This high level of accountability provides each child with a baseline in order to reach objective goals. Two key outcome measures were identified: The Gross Motor Function Measure (GMFM) and the Pediatric Evaluation of Disability Inventory (PEDI). GMFM is a clinical tool designed to evaluate change in gross motor function in children with cerebral palsy and has been used to assess children post-acquired brain injury [32]. The GMFM scores were not included in this study at this time. Both the GMFM and PEDI have been proven reliable and appropriate for school-aged children [2,33].

The Pediatric Evaluation of Disability Inventory is a clinical assessment tool that has been shown to be a reliable and valid assessment of impairment of functional mobility in children [2]. The physical therapy department administered and collected the PEDI assessments during the 2013-2014 school year. The PEDI has been used to evaluate children with brain injury including cerebral palsy, seizure disorders, brain tumors, and rare congenital disorders pre- and post-admission to inpatient rehabilitation. It is a scale that has been consistent in "detecting subtle differences in young children with slowly emerging functional skills" [33,34]. The PEDI has shown to be an appropriate evaluation scale for children with brain injury with severe impairment with or without test adaptation [35].

Clinical Objective Measures include (but are not limited to) range of motion, strength, spasticity, sensation, quality of movement, and skin integrity. Formal testing may be conducted as well to provide standardized values and a benchmark for comparison with future assessments.

Speech and Language Therapy: The speech and language services at the school are intensive and dynamic. In most programs, the child's disability is often the primary focus of caregivers and educators.Children's interests and abilities may be masked by their disability, particularly in cases of sensorimotor difficulties, which interfere with the ability to articulate speech, manipulate objects, and make interests and intents known to others. As a consequence, choices available to individuals with TBI are limited, and the person beneath the brain injury is not

really known. This is not the case for the children served at the school because the speech department establishes relationships with children based on the world around them. Speech Language Pathologists (SLPs) aim to reduce the handicaps in students' daily environments and make their world a more accessible place.

In the speech department, the core function of language is to make content of mind, that is: make personal ideas, intents, and feelings, public and known to others [36]. Language develops because children are motivated to interact with people and their environment. SLPs use that motivation and intentionality to fuel their speech sessions.

The speech department paradigm at the school has incorporated in its design the recognition that behavior is context sensitive. Feuerstein, Pena, and others have advocated for the dynamic assessment and treatment of children. Dynamic assessment and treatment refers to the technique of modifying the linguistic and non-linguistic aspects of assessment contexts to get a sense of the range of behaviors children are capable of, and to understand which characteristics of tasks challenge children, and which characteristics facilitate performance.

Sessions are intensive and coupled with the intentionality model. The ntentionalitymodel builds on the child's engagement in a world of persons and objects, in an effort to reduce the tension between engagement, and difficulty learning a language that is required. Bloom, Tinker and Scholnick [37], summarize the significance of the intentionality model by stating "children learn language in acts of expression and interpretation; they work at acquiring language; *and* all aspects of a child's development contribute to this process." [37]. Most children receive 5 sessions for 60 minutes per week. Sessions are tailored to meet the cultural and linguistic needs of the child. SLPs strive to get the voice of each child known to their families, friends, caregivers, and medical providers and use every context to facilitate language. There is a range of augmentative and alternative communication (AAC) systems for each level of development: from the Tobii Eye Gaze to a single message switch, to a basic picture exchange system. The department believes in creating the context for situations that are meaningful, which will lead to increased outcomes.

Measurements include initiating communicative turns and increased vocabulary, spontaneous initiations, use of devices, sentence development, mean length of utterance (with AAC systems), and pragmatic language. Some of the projects include: School Elections, Food Drive, Clothing Drive, and Ask Student Column.

Health and Wellness Programmatic Supports and Management

The school nurse coordinates the child's health care planning and delivery at school and supports the child's learning. The delegation of health care to non-licensed personnel and supervision are roles that the school nurse assumes according to state nurse practice acts. Throughout the school year, the school nurse continues to provide skilled nursing care and case management for the health support of the child with special health care needs.

As part of the child's education and health planning team, the school nurse at the private special education school secures permission from parents and contacts medical providers, develops the Individualized Health Care Plan (IHCP), and ensures that information is current and shares it team members as appropriate. The school nurse also gathers medical and nursing information including immunizations. At admission, the program nurse assesses student health care needs including cultural aspects related to family beliefs. The program's nurse shares information from community health care providers as appropriate and necessary to collaboratively plan for the child's health care in educational environments other than the school building, such as transportation and field trips, including formal training needs of school staff regarding a child's health care plan. The program nurse provides plans to obtainand maintainappropriate medical supplies and equipment.

Additionally, the school nurse starts the day by making rounds to check attendance and make sure that students who come are provided with the care as indicated in their IHCP (including seizure action plan, allergies/anaphylaxis medication plan, asthma medication plan, non-asthma/non-allergy medication plan, non-medication plan). Most importantly, the program nurse delivers nursing care, medication, and treatment to the students. Therefore, the records maintained by the school nurse were instrumental to this study to indicate whether changes to health and hospitalizations were noted after an intensive therapeutic intervention (PT, OT, ST).

For the purposes of this study, the school nurse reported retrospective information regarding the student hospitalizations, medication, and changes thereto.

Methods

Participants

Six original students attended the first year of enrollment (2013-2014). Two of four of the outcome measures were reported for the 2013-2014 school year. The second-year students' academic, speech, physical therapy, and visual education data were reported. Of 27 students enrolled during the second year, a total of 14 students' data are included, after factoring exclusion criteria,5 of which were hospitalized for more than 5 days for orthopedic surgeries and were included in data analysis for PEDI comparison only.

Exclusion criteria

Exclusion criteria included: 1) Hospitalization related to musculoskeletal surgery; 2) No longer an enrolled student; 3) Part-time student enrollment (i.e., late start or early end to the school year).

Study design

A retrospective case series was reviewed and approved by the ethics board of the school's board of directors. The data forthe six students enrolled at a private special education school are reported, pre- and post-first year (2013-2014) of enrollment. Surveys to collect data onschool attendance records and health

records were distributed. Cortical Visual Impairment Ranges, Preschool Language Scale-5 (PLS), Brigance Inventory of Early Development III, PEDI raw and interval scores (self-care, mobility, and social functioning domains) for students during the 2013-2014, 2014-2015 school years were evaluated and reported per department records. School health records (change in medication or hospitalizations), related service mandates and frequency, quarterly progress reports, and classroom ratio were investigated for data collection.

School setting

The private special education school program established a multidisciplinary therapeutic and academic setting for six original students during the 2013-2014 school year. The second year of enrollment comprised 27 students with brain-based disorders of school age (5-21 years). The diagnosis of the student population included acquired brain injury as a result of seizure disorders, post-birth injury, cerebral palsy, and TBI. The daily schedule incorporated a push-in and pull-out model according to the children's current IEP-related service mandates (including occupational therapy, physical therapy, speech and language therapy) in addition to daily direct instruction during academic sessions, as well as adaptive physical education in the form of Conductive Education. Intensity of related service mandates were increased based on professional observation of the original student population after initial evaluation. These evaluations were completed during the initial session after school admission. During the second year of operation, the program included vision education services for children with Cortical Visual Impairment (CVI) and other visual impairments. Each department conducted assessments and outlined therapeutic interventions and outcomes related to the child's annual goals.

Outcome measures

This article reports the results of students (years 2013-2014 and 2014-2015) in 1)Pediatric Evaluation of Disability Inventory (PEDI): Self-Care, Mobility, and Social Functioning; 2) Cortical Visual Impairment (CVI) Ranges; 3) Speech Assessments: Brigance and Preschool Language Scale-5 (PLS) assessments; 4) Student Demographics: IEP Mandates and Health Outcomes pre- and post-admission to program; 5) quarterly progress reports.

Pediatric Evaluation of Disability Inventory (PEDI): The Pediatric Evaluation of Disability Inventory is a clinical assessment tool that has been shown to be a reliable and valid assessment of impairment of functional mobility in children [2]. The functional domains of the PEDI are divided in 3 subdivisions: Self-Care, Mobility, and Social Functioning. The assessment addresses caregiver assistance and modifications needed for improved participation.

The PEDI is based on the World Health Organization model of disability and validated for normative values for children from age 1 to 7.5 years and has an activity scale that extends beyond basic functional skills,which is intended to examine recovery of basic skills needed for return to the community. A participation scale that emphasizes life roles and assesses levels of participation in the community and school environments is also included. However, due to the overwhelming report of parents completing most of evaluating tasks because of time constraints (i.e.,dressing in the morning to make the school bus on time), caregiver participation scores were not included in data analysis. The PEDI data collected for this study were distributed by the physical therapist at the school. During 2013-2014, one therapist collected and reviewed all data with parents. During the second year of school enrollment (2014-2015), four therapists collected the data from parents, teachers, and paraprofessional staff who work closely with evaluated student.

Cortical Visual Impairment Range (CVI Range): The school has employed a collaborativeapproach among parents, therapists, educators, and members of the medical community, such as ophthalmologists and optometrists. All school staff have been exposed to the foundational concepts of CVI Range and the scoring process. In order for students to utilize their functional vision throughout the day in multiple settings, accommodations and modifications are implemented throughout the various therapies and in the classrooms. Each student at the school had a highly individualized program to maximize the potential to improve his/her visual processing abilities. With this foundation, the individual student's visual processing abilities have improved, as is evident by individual improvements on the CVI Range.

The CVI Range is scored from 0-10 and is grouped into three phases. CVI Ranges were compared for the students in the 2014-2015 school year (because vision services were not available during the initial year of the program:

Phase I of CVI=scores 0-3=developing visual behaviors

Phase II= scores 3-7= Integrating Vision with Function

Phase III= scores 7-10= Using Vision for Learning

0=No functional vision

10= Typical functional vision

Preschool Language Scale-5: The Preschool Language Scale-5 (PLS) was used to obtain a clinical assessment of the child's level of Auditory Comprehension as well as Expressive Communication domains. It is a reliable and valid tool when used as a descriptive criterion reference to assess a child's language development. Additionally, it allows for repetitions and accommodations for students with physical and cognitive impairments. The test was modified to accommodate our special population. Because of the modifications of standard procedures, norm referenced scores were not used. The modifications of the test allowed qualitative information about the student's language comprehension and expressive language abilities. The raw data scores were compared at the beginning and end of the 2013-2014 and 2014-2015 school years. Measures from children with disabilitiesare not used to obtain normative data as this would lower the mean standardized score of the test and negatively impacts the test's ability to separate and identify typically developing children and those with disorders [38]. As a result, standardized scores for our student population cannot be reported and raw scores are used for pre- and post-comparatives and descriptive purposes only.

Brigance Inventory of Early Development III: For the children who were older than 7.5 years, the Brigance criterion-referenced Inventory of Early Development III (IED III) was used to assess and track the speech and language developmental skills of the students. Each sub-linguistic skill (e.g., Prespeech expressive communication, Prespeech receptive language, following directions) is regarded as distinct, and there is not a cumulative score associated with a skill area or sub-area [39]. Furthermore, there is currently no available test that can be used to accurately measure the language competence of a child with TBI, resulting in a standardized score [40].

Data Analysis

Statistical tests were conducted using R Software Version 3.2.1. [www.Rproject.org at the Department of Statistics of the University of Auckland in Auckland, New Zealand] and G Power 3.1 software [University of Dusseldorf] [41-43], with significance level set at P<.05. Paired *t* tests were applied to examine baseline and post-annual school intervention differences within the PEDI (school years 2013-2014 and 2014-2015) and CVI ranges (year 2014-2015). Independent *t* tests were used to examine the gaps between group differences in change of scores.

IEP-Related Service and Class Ratio Mandates

The students reviewed received 10-15 hours per week of Related-Service (OT, PT, ST, VS) Intervention during the school years 2013-2014 and 2014-2015 as indicated on their Individualized Education Plan (IEP). Prior to admission to the post-acute brain injury special education school, students received an average of 5-10 hours of intervention in a larger class setting without Direct Instruction. Each student included in the study received approximately 3-5 hours of Direct Instruction per week.

Results

Cortical Visual Impairment Range (CVI Range)

Paired sample t-testing was conducted to compare students' scores on The CVI Range during the summer of 2014 and the summer of 2015 to determine if there was significant improvement in vision during this time period. The CVI Range yields a range of scores so 3 t-tests were conducted. The first t-test only used the minimum scores from the range in each time period. This test found that t(7)= 7.666, p=.0001 with a mean difference of 1.18. The second t-test compared the means of the score ranges. This test found that t(7)=9.01, p<.0001 with a mean difference of 1.22. The third t-test compared the highest value on the first assessment with the lowest value on the second assessment. This test found a t(7)=2.12, p=.0715 with a mean difference of 0.375.

Our findings show that when comparing lower scores or mean scores, the average gain was about a full point on the CVI Range, and this gain is statistically significant at the α=.999 level. Even comparing the highest value on the first assessment with the lowest value on the second assessment, which minimizes the detection of any possible gains, the result is still a gain of over a third of a point, being statistically significant at the α=.9 level. See Appendix II for detailed list of CVI Ranges per student.

Pediatric Evaluation of Disability Index (PEDI)

For increased accuracy and sample review, the five students that were hospitalized during the years in question were included for PEDI scoring. See Appendix I for raw and scaled scores. Paired sample t-testing was conducted to compare Self-Care, Mobility, and Social Functioning as measured by the Pediatric Evaluation of Disability Index (PEDI) during 2013, 2014, and 2015 to determine if there was significant improvement in those areas during that time period. First, 2013 and 2014 were compared on Self-Care. This test found that $t(5) = 2.208$, $p=0.078$, with a 90% Confidence Interval of 0.003 to 0.079 and a mean difference of 0.04. This result implies that with 90% confidence there is a non-zero difference in Self-Care between 2013 and 2014 and that this gain is between 0 and 0.08. The test for Mobility found that $t(5) = 2.33$, $p=0.067$, with a 90% Confidence Interval of 0.008 to 0.111 with a mean difference of 0.06. Again, with 90% confidence, there was a non-zero difference in Mobility between 2013 and 2014 and this difference is between 0 and 0.111. For Social Function the test found $t(5)= 2.66$, $p=0.0451$, with a 90% Confidence Interval of 0.03 to 0.24 with a mean difference of 0.138. With 90% confidence, there is a non-zero difference in Social Functioning and this difference is between 0.03 and 0.24.

Paired sample t-testing was also conducted during the period between 2014 and 2015. For Self-Care, $t(12)=-0.56$, $p=0.58$; for Mobility, $t(12)=1.346$, $p=0.203$; and for Social Functioning $t(12)=1.748$, $p=0.106$. To confirm this result, Hoteling T^2 was conducted to determine if multivariate gains were present that would not appear in the univariate t-tests; T^2 (3,22) = 0.44, $p=0.72$. This result is consistent with the results of the paired sample t-tests. Therefore, based on these analyses, while there were substantial gains between 2013 and 2014 across all three domains, there were no statistically significant gains in any domains between 2014 and 2015.

Preschool Language Scale-5 (PLS), Brigance Inventory of Early Development III

The collected data during the school year 2013 to 2014 shows that all six students showed an average improvement in their overall auditory comprehension and expressive communication scores. Most of which doubled their communication abilities as compared with the time of the admission assessment. (See Appendix III for detailed scores for each student.) Due to the fact there is not an acceptable commercially available assessment that quantifies speech and language impairment in children with severe cognitive delay and brain injury, assessments are used to allow for self-comparison, and thus do not provide a standardized score option when below the first percentile rank. Research demonstrates that standardized language tests do not consistently diagnose children correctly when comparing raw scores alone [40], therefore, criterion reference assessments were used as a guidance when measuring progress. Without standardized scores, the statistical data analysis was not possible. Nevertheless, the similar speech improvements gains

seen in 2013-2014 were observed during the school year 2014-2015. Three students (students 10005, 10021, 10004) under 7 years 11 months of age showed an increase in their skills of or more than 100% in the area of auditory comprehension, whereas in the areas of expressive communication the growth was over 155% during the first year and second year in most cases. Three students (10011, 10019, 10007) ranging in the ages of 7 years 11 months to 18 years showed an increment of their overall language development of more than 80% during their first year when speech intervention was tailored and sessions were strictly student led. One student (10010) showed a more discrete growth of auditory comprehension of 33% during the first year since the admission date,whichmay be related to age at admission(16 years) when compared with peers.

Academic Outcomes

Quarterly progress reports allow for analysis of student progression towards achieving academic IEP goals as reported by each child's teacher. Data collected for quarterly progress reports during the 2014-2015 school year show that all students made considerable progress towards academic IEP goals throughout the school year. Overall, students made progress towards 95.8% of literacy IEP goals and 100% of math IEP goals (Appendix A).

Health Outcomes: Attendance, Related Service Mandates, Hospitalization, Medication Changes

Retrospective Wellness Surveys were sent to every student at the school for collection of parent satisfaction information and to compare the hospitalization and attendance rates. Because of the inconsistent reporting and data received from the families, comparisons to pre-school admission were not made. IEP-Related service and class ratio mandates pre- and post-admission to the private special education brain injury school are included in Appendix B. Information about the student health and attendance during the 2014-2015 school year is included in Appendix C.

Discussion

It is postulated that the CVI range and social functioning scores were statistically significant because of the intensive multidisciplinary intervention in the "school setting." We will discuss in turn each of the domains of function that the children made progress in as it relates to the existing literature. Additionally, we suggest a hypothesized reason for why a multiple disciplinary approach supports the neuroplastic changes necessary for the children's progress.

There are significant gaps in the existing literature regarding best practices for multiple disciplinary treatment for children with chronic acquired brain injury within a school-based setting [44]. Much of the current literature is discipline specific and does not evaluate a team-based approach to care of students with brain injuries. Existing research evaluates students with recent brain injuries returning to school with less severe motor difficulties than participants in the current study, and much of the research evaluates level of participation or community engagement as outcome measures [44-47]. Studies have shown that students often require additional supports to participate in the classroom environment fully and many have long-term executive cognitive functioning deficits [48].

Unfortunately, the existing research on pediatric ABI has limited evidence-based treatment protocols to facilitate the most effective attainment of goals, promote quality of life, and promote improvement in functional ability. There are limited best practice guidelines and position statements produced in occupational therapy, physical therapy, speech and language therapy disciplines for students with acquired brain injury. Notable exceptions are constraint induced movement therapy for children with hemiparesis and vision education that use established protocols for children with cortical vision impairment [49,50].

When it comes to CVI assessment, early detection isparamount to make sure that the children are able to achieve their full potential. Therefore, to help all children that may have CVI, it is extremely important to develop assessments that make it possible to identify these children regardless of cognitive or other limitations, such as being non-verbal communicators [51]. Christine Roman- Lantzy [23], developed a reliable formal assessment that is a valid instrument for assessing the widerange of students who have Cortical Visual Impairment. The validity and reliability of the CVI Range is based on its internal consistency and on test/retest reliability. Roman argues that the changes in functional vision within a given time frame are due to the environment rather than to the fluctuating visual abilities of the child [7]. Given a modified environment and appropriate accommodations, students with CVI are able to improve their functional vision. Based on neuroplasticity research, students have the ability to use different parts of their brain to process visual information, even in cases where certain areas of the brain that are usually designated for specific visual processes have been damaged [52].

Key findings from the study include functional reported progress observed in every domain. The carryover of significant social functioning and visual integration in academics demonstrates the relevance of intense multidisciplinary intervention being provided in a "school setting." The academic setting is one of the hallmarks for childhood development and further research is warranted to investigate how and why students achieved such overwhelming progress in 1years' time. The results support a task-specific and repetitious paradigm in an educational setting, in addition to intensive treatment, which is supported by evidence in the literature.

It is difficult to evaluate multimodal treatment approaches because the number of treatment styles, techniques, and different therapists produces a large number of variables [53]. Consequently, progress cannot be attributed solely to a specific discipline, and it makes it difficult for techniques to be replicated in a targeted, focused therapy program.

Protocols and best practices for adults with acquired and traumatic brain injury are well established [45,54-56]. Attempts can be made to apply these techniques to a pediatric acquired brain injury population; however, in children, the brain is

continually undergoing neuroplastic changes associated with the process of typical development. Adults with brain injury have the benefit of previously established motor plans and underlying cognitive reserve that allows them to regain or re-develop skills at a faster rate after injury. Children who have brain injuries very early in life do not have concrete or well-established cortical maps. This difference is an example of habilitation in contrast to rehabilitation, meaning building new skills and functional abilities versus regaining previously established abilities [25].

On the basisofthe understanding of the limited available research, the multiple disciplinary program described in this study was (built, founded, established) on general and theoretical principles of neuroplasticity to promote recovery and development of neural pathways. Existing neuroplasticity research supports the following key tenants to support changes in cortical mapping: use of active exploration in an enriched environment, increased repetitions of motor tasks (massed practice), intrinsic motivation and engagement for completion of tasks, and task specificity [28]. The school program was designed to promote these principles, with intensive services allowing for carryover of learned skills in each discipline [57]. The school environment encourages/facilitates active participation of children with Direct Instruction, tailored goals, biking and standing programs, and individualized sensory diets [55,58,59].

Study Limitations

The study limitations include a sample of convenience,(as students were all enrolled in the school program), a small sample size, a retrospective versus prospective study design, a diverse, heterogeneous population, and the absence of a prior power analysis. Additionally, many outcome measures were based on parent interview and reporting and had poor inter rater reliability due to varied therapist application. These limitations reduce the generalizability of our study's findings.

Implications for Future Studies

Multidisciplinary rehabilitation has shown to improve functional outcomes in adults with acquired brain injury [2]. In addition, late-onset rehabilitation has shown improved gains in functional mobility for both adults and children [3,4]. Further investigation of children with severe disabilities is warranted because no study to date has examined the effects of increased multidisciplinary therapeutic intensity in a school setting for children with brain injury. Because of the heterogenous diagnostic population of children who suffer from brain-based disorders, it is difficult to perform a randomized control trial with students of various prognostic and physical markers with similar etiologic brain injury. With the evidence-baseddocumentation [5-9], of high-intensity intervention and interdisciplinary services for children with brain injury, it is recommended that future researchers report on the individual effects of said academic and related services. This would include case series, single-subject designs, and long-term cohort studies reviewing the effects of intensive intervention in a school setting. A cohesive and collaborative cognitive, communication, and functional measure does not exist for children with severe disabilities (i.e., the non-verbal and non-ambulatory population). This population relies heavily on clinical observation and modified validated assessments to quantify progress. However, more research and thus standardized outcomes are needed that reveal cognitive, social, and functional status in the profoundly disabled child with chronic brain injury.

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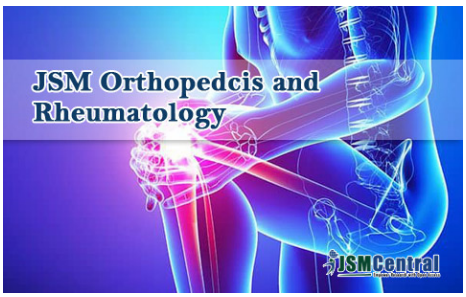

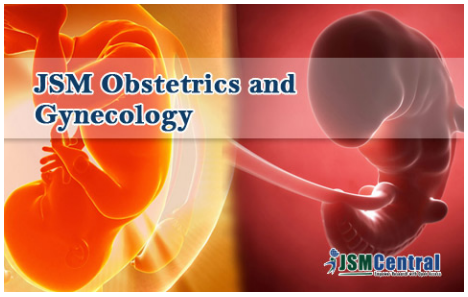

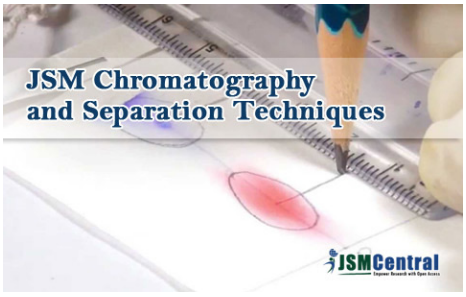

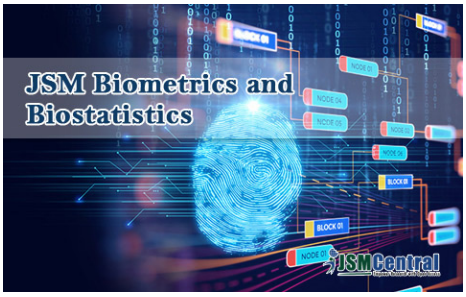

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