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RESEARCH PAPER

Improving neuropsychological function after chronic brain injury with hyperbaric oxygen

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Abstract

Purpose. One suggested treatment for chronic brain injury (CBI) is the use of hyperbaric oxygen therapy (HBOT). The present study was an evaluation of neuropsychological improvement after HBOT in CBI patients.

Method. Study 1 compared test–retest results of 21 CBI children treated with HBOT against test–retest results of 42 untreated brain injured and normal children. Study 2 compared 21 CBI adults treated with HBOT against 42 untreated normal and brain injured adults. In each study, subjects received pre and post assessments to evaluate neuropsychological function.

Results. The HBOT-treated children showed significant improvement when compared with the two control groups on measures of daily living, socialization, communication, and motor skills. The treated adults made significant gains in all neuropsychological areas tested as compared to controls.

Conclusion. The studies were strongly supportive of HBOT as a treatment for lessening the neurological impact of CBI. These studies indicate that HBOT can be an effective aid in ameliorating the neuropsychological and physiological effects of CBI. The absence of a clear sham HBOT treatment group is an issue as it could be that there was a placebo effect, but it should be noted that the controls were receiving more traditional interventions during the study.

Keywords: *Hyperbaric, neuropsychology, cognitive, brain injury, child, adult, treatment, HBOT*

Introduction

Due to improvements in treatment and in diagnosis, the number of child and adult survivors of brain injury who have significant residual deficits have increased in number to an estimated 2–5% of the population in the United States. These injuries have substantial effects on the personal, social, and vocational lives of these individuals as well as their family and friends and society as a whole. This has resulted in the search for potential treatments which can reverse or ameliorate the effects of these chronic problems.

One possible treatment is the use of hyperbaric oxygen therapy (HBOT). Originally developed as a treatment for the 'bends' in divers, HBOT with chronic brain injuries is a technique in which the individual is administered 100% oxygen at greater than the normal pressure to allow additional oxygen to dissolve into the blood plasma, therefore increasing the amount of oxygen available to the cells of the body and the brain. Neubauer and Walker [1] have argued that HBOT can improve the cerebral blood flow by improving the functioning of neurons made dormant by a neurological disorder as well as stimulate axonal growth and increase the ability of normal neurons to better function and communicate with other neurons.

However, most of the evidence for the success of HBOT is anecdotal rather than scientific [1,2]. A recent unsigned review in the journal *Brain Injury* [3] concluded that there were few useful studies on acute or chronic brain injury from which clinical conclusions could be reached.

A review of the literature for this paper revealed only a handful of good studies which addressed the effectiveness of HBOT in improving cognitive function in chronic brain injury. Hardy et al. [4] conducted a double blind study in which both

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groups received 40 sessions of HBOT but at different levels. The experimental group received 100% oxygen under pressure while the control group received room air under pressure. One-third of 111 children included were untestable on the tests used. Children in both groups showed improvement but the experimental group was not better than the controls.

On the other hand, Zhang et al. [5] explored HBOT in the treatment of neuropsychological impairments in 86 patients with senile cerebral infarction (CI). Subjects were treated with HBO plus routine medication or routine medication only. The results showed that HBOT was superior to treatment with medication alone. While these were among the strongest neuropsychological studies, most previous studies have shared a lack of proper assessment of patient improvement, few subjects, and inadequate lengths of treatment or type of treatment.

There is clearly a need to study whether this technique is indeed a promising treatment or only a placebo in the treatment of chronic brain injury. There are two primary questions. First, does HBOT actually improve physiological brain function in individuals with chronic injuries? Second, if such changes do occur, do they lead to improvement in cognitive and behavioral function?

An initial study [6] examined changes in SPECT scan metabolic indices both before, during, and after hyperbaric treatment studies was designed to identify metabolic changes. This study showed clear improvement in metabolic performance after a series of hyperbaric treatments. There was an overall increase in blood flow between the baseline SPECT and the post-SPECT for the RH, LH, and cortical measures. The study also found that post-SPECT blood flows were higher than the mid-treatment SPECTs for the RH, LH, and cortical measures. The blood flow increase was found primarily in the cerebral hemispheres (including the basal ganglia), but not in the pons and in the cerebellum.

The purpose of the present study was to determine whether HBOT could result in more improvement in neuropsychological measures than seen on typical test–retest over the same period by comparable brain injured and normal subjects who were untreated. More basic measures of neuropsychological function were employed so as to detect changes in basic functions that would likely be most sensitive to short term changes in brain function. The paper reports on two studies, one with children (Study 1) and one with adults (Study 2). It was hypothesized that there would be pre–post changes in response to HBOT when compared to changes over the same time period in untreated brain injured and normal controls.

Study 1: Cognitive and behavioral improvement in children

Method

Subjects. Sixty-three subjects were tested on a pre and post neuropsychological battery. Twenty-one of the subjects were children who were already scheduled to receive Hyperbaric Oxygen Therapy (HBOT) who agreed to participate in the study. Each experimental subject was chosen from patients referred by physicians for HBOT because of the presence of chronic brain injury. The most common diagnosis was cerebral palsy. An additional 21 brain disordered subjects who had previously been tested and retested in the course of a brain injury support program were included, as well as 21 normal controls who had been tested as a part of past research studies. All patients in the two injured groups had chronic disorders with a very early age of onset. All were reported by family as having reached and maintained a static level of functioning for at least 1 year despite other methods of treatment. Consent for participation in the study was secured from the subject's parent or legal guardian using forms approved by the Nova Southeastern University Institutional Research Board. All study procedures were approved by the Nova Southeastern University Institutional Research Board.

The average age of the HBOT group was 55.43 months ($SD = 46.29$) with 1.19 ($SD = 2.73$) years of education. There were 10 females and 11 males. They received an average of 28.81 ($SD = 15.27$) treatments over 27.29 ($SD = 29.18$) days. All patients were Caucasian. The average age of the chronically injured group was 59.67 months ($SD = 43.24$) with 1.10 ($SD = 2.63$) years of education. There were nine females and 12 males. The normal control group had an average age of 67.00 months ($SD = 43.00$) and 1.57 ($SD = 1.99$) years of education. There were nine females and 12 males in the group. One-way ANOVAs for age and education showed no differences between the groups and a chi-square showed no difference for gender. The most common diagnoses made by the subject's medical doctors were cerebral palsy (29%), stroke (12%), traumatic brain injury (26%), Lyme disease (7%), anoxic ischemic encephalopathy (17%), and other (9%). Medications were stable over the 1-month course of the study.

Pre and post testing. All subjects in both the hyperbaric and control groups were evaluated using the Vineland Adaptive Behavior Scale. The Vineland Adaptive Behavior Scales [7], a revision of the original Vineland Social Maturity Scale, have long been used in the evaluation of behavior. The Vineland assesses four areas of general function: daily living skills, communication, social skills, and motor skills. The full interview edition has 577 items, and information is gathered through a semi-structured interview. The Motor Skills Domain is intended for children less than 6 years old but was used with the entire population for this study due to the prevalence of disabling motor problems in this population regardless of age. A fifth score (Total) is calculated by adding the four subtests.

The Vineland was administered at both the pre and post testing sessions using a parent as the informant. For the hyperbaric clients, this was before the beginning of hyperbaric treatment and approximately 4–8 weeks later depending on the length of their initial HBOT treatment. Subjects in the two control groups were selected because they had taken the test twice with similar 4–8-week test–retest intervals.

Results

The initial scores of the HBOT group were generally poorer (lower) than either of the two control groups, suggesting that their level of injury was greater. A multivariate analysis of covariance was conducted using Group (HBOT, brain injured controls, normal controls) as the between variable and the four Vineland pre–post difference scores as the repeated measures. Age, education, and gender were employed as covariates. The multivariate results showed a significant difference among the groups in terms of change scores. ANOVAs were completed comparing the groups across each change score and each covariate. As can be seen in Table I, the net change was much greater for the HBO group than for either of the control groups. *Post-hoc* *t*-tests showed that the HBOT group showed more gain than the brain injured controls on all measures and was greater than the normal controls on all measures except Communication.

Correlations were calculated with each change measure and number of treatments in the HBOT group. These correlations were non-significant. Close examination of the current data suggested that there was a large amount of variability in response to treatment among the children as seen in the large standard deviations associated with each of the improvement variables as can be seen in Table I. This may suggest that the children may be divided into responders and non-responders, which is evident even in the relatively early stages of the treatment. Duration of treatment failed to correlate with any of the variables in the overall group or in the subgroups.

To investigate this, the children were divided roughly into responders and non-responders by splitting the group at the median score. In the 10 children below the median (non-responders) the correlations between number of treatments and the change scores on the Vineland range from −0.28 to 0.18 with the change in total score correlating 0.098 with treatments. In the responders, the correlations between number of treatments and the change measures range from 0.16 to 0.53 with the change in the total score correlating 0.47 with treatments. This result may suggest that while there is a dose–response curve in the responders, this does not exist in the non-responders.

Study 2: Cognitive improvement after HBOT in chronic adult injuries

Method

Subjects. Sixty-three subjects were tested on a pre and post neuropsychological battery. Twenty-one of the subjects were adults who were already scheduled to receive hyperbaric oxygen therapy (HBOT) who agreed to participate in the study. An additional 21 brain injured subjects who had previously been tested and retested in the course of a brain injury support program for chronic brain injuries, in addition to 21 normal controls who had been tested as a part of past research studies were also included. All patients in the two brain injury groups had chronic brain injuries that had lasted more than 2 years. All were reported by family as having

Table I. Pre and post means, SDS, and *F*-tests for all child variables.

	HBOT		Group Brain injured		Normal controls			
Variable	Mean	SD	Mean	SD	Mean	SD	*F*(2,56)	*P*
Age (months)	55.43	46.29	59.67	43.24	67.00	43.00	0.37	0.693
Education	1.19	2.73	1.10	2.63	1.57	1.99	0.22	0.804
Motor – change	9.86	11.42	0.10	2.91	3.77	6.42	8.50	0.001
Communications change	9.71	7.73	1.48	1.72	6.30	2.83	15.25	0.000
Daily living – change	10.81	8.04	1.19	2.79	5.84	5.08	14.85	0.000
Social skills – change	13.19	12.68	0.95	3.25	5.97	4.43	12.48	0.000
Total – change	43.57	31.45	3.71	5.99	21.88	7.81	23.11	0.000

reached and maintained a static level of functioning for at least 1 year despite other methods of treatment. Consent for participation in the study was secured from the subject using forms approved by the Nova Southeastern University Institutional Research Board. All study procedures were approved by the Nova Southeastern University Institutional Research Board.

The average age of the HBOT group was 40.76 (SD = 17.8) with 12.52 (SD = 1.78) years of education. There were five females and 16 males. They received an average of 35.38 (SD = 18.7) treatments over 34.52 (SD = 17.7) days. All patients were Caucasian. The average age of the chronic brain injury group was 39.19 (SD = 16.0) with 12.14 (SD = 2.69) years of education. There were four females and 17 males. The normal control group had an average age of 37.48 (SD = 12.1) years and 13.52 (SD = 2.4) years of education. There were six females and 15 males in the group. The most common diagnosis were head trauma (26%), hypoxia (7%), anoxia (21%), stroke (26%), and miscellaneous other (20%). Medications were stable over the course of the study (which averaged just over a month). One-way ANOVAs for age and education showed no differences between the groups and a chi-square showed no difference for gender.

Pre and post testing. All subjects in both the hyperbaric and control groups were given a 45-min test battery at both the pre and post testing sessions. For the hyperbaric clients, this was before the beginning of hyperbaric treatment and approximately 4–8 weeks later depending on the length of their initial HBOT treatment. Subjects in the two control groups were selected because they had taken similar tests with a similar 4–8 week test–retest intervals.

Test material. The initial test battery was longer than the battery described here. However, some of the tests proved too difficult for the HBOT clients and so were removed from the battery. For all tests scores were the actual number of correct items (including the LNNB scales which are normally scored for number wrong) Further information on each test may be found in Golden et al. [8].

Stroop (W, C, CW). The Stroop consists of three pages. The W page consists of the words RED, GREEN, and BLUE. The client must read these words as fast as possible for 30 s. The C page consists of color patches that are printed in red, green, or blue. The client must name these colors as fast as possible for 30 s. The CW page consists of the words on W printed in the colors on C in such a way that the word and color does not match (e.g., RED printed in blue ink). The client must name the color of the ink as quickly as possible, ignoring the word the ink spells.

Luria-Nebraska neuropsychological battery. Four scales were used from this battery. The motor scale (Scale C1), the Tactile Scale (C3), Receptive Language (C5), and Expressive Language (C6).

Word fluency. Clients are asked to generate as many words as they can in five categories. Each trial lasts 1 min. The categories for each trial are: (1) Letters starting with C; (2) Letters starting with F; (3) Letters starting with L; (4) Animals; and (5) Food.

Logical memory. Two stories were read from the logical memory scale of the Wechsler Memory Scale – Revised. This yielded two scores: immediate recall and delayed recall after 30 min.

Total. This score was the sum of the number correct for all 10 subtests.

Results

For all neuropsychological variables, analysis was performed on a difference (improvement) score between the first and second test administrations for all groups. For all variables, the initial level of the HBOT group was lower than that of the brain injured or normal controls indicating that they had more severe residual deficits.

The groups did not differ significantly on age, education, or gender overall. Nevertheless, these were included as covariates in case there were specific effects related to individual dependent variables. At the 0.01 significance level, age was related to the Stroop Color–Word interference variable but not to any other score. Neither gender nor education was related only to any of the neuropsychological difference scores. In addition, the groups did not differ on the number of days between the test and retest (duration). Overall, these variables had minimal impact on the results, which were the same whether the covariates were included or not. The following results were derived with the covariates included.

Multivariate analysis. The results of a one way (group) multivariate analysis of variance across all 10 neuropsychological difference scores revealed significant effects for Group (Wilkes Lamda = 0.294, $F = 3.97$, $P < 0.001$) but not for any of the covariates. *Post-hoc* univariate analyses were conducted across groups for each neuropsychological variable.

The results of the ANOVAs for the effects of the Group variable indicated that nine of the 10 variables showed differences at the 0.01 level. These are reported in Table II. The only variable that failed to

Table II. Pre and post means, standard deviations, and *F*-tests for all adult variables.

Variable	HBOT Mean	HBOT SD	Group Brain injured Mean	Group Brain injured SD	Normal controls Mean	Normal controls SD	*F*(2,56)
Age	40.76	17.76	39.19	15.99	37.48	12.10	0.24
Education	12.52	1.78	12.14	2.69	13.52	2.40	1.98
Test–Retest days	34.52	17.68	32.67	1.50	30.05	9.09	0.80
LNNB Motor	8.88	8.12	−1.85	12.74	0.97	1.53	8.54*
LNNB Tactile	3.48	6.26	0.54	0.52	0.71	0.72	4.91
LNNB Receptive	5.53	9.26	0.88	0.87	1.19	1.10	5.23*
LNNB Expressive	12.24	16.38	0.88	1.26	1.84	2.18	9.83*
Stroop Word	7.52	11.81	0.10	1.22	0.52	2.46	6.36*
Stroop Color	9.67	8.45	−0.43	1.21	0.71	1.35	23.65*
Stroop Color–Word	7.19	8.71	−0.33	1.39	1.71	1.52	18.14*
Verbal Fluency	3.35	4.98	−0.19	1.29	0.43	2.06	7.90*
Logical Memory Recall	2.71	3.09	0.67	2.99	−0.48	3.28	6.81*
Logical Memory Delay	3.90	2.76	0.86	1.56	0.48	1.97	21.08*
Total	62.73	42.01	1.13	13.27	8.10	6.69	35.97*

show significance at the 0.01 level was the LNNB Tactile scale, which was only significant at the 0.011 level, just missing the cutoff of 0.01. Six of the 10 variables were significant at the 0.001 level. *Post-hoc t*-tests showed that the HBOT group made more gains on all variables than either of the control groups.

Correlations with number of treatments and duration of treatment. Number and Treatments and Duration of Treatment correlated 0.287 (df = 62, $P < 0.05$) with each other. Treatments also correlated with changes on LNNB Motor (0.325, $P < 0.01$), LNNB Tactile (0.306, $P < 0.02$), LNNB Receptive (0.358, $P < 0.01$), LNNB Expressive (0.361, $P < 0.01$), Stroop Word (0.575, $P < 0.001$), Stroop Color (0.743, $P < 0.001$), Stroop Color–Word (0.525, $P < 0.001$), Verbal Fluency (0.403, $P < 0.001$), Logical Memory Recall (0.352, $P < 0.01$), and Logical Memory Delay (0.477, $P < 0.001$). This suggests that there is a moderate dose–response curve at this level of treatments. Duration of treatment correlated with only Verbal Fluency (0.375, $P < 0.01$). This suggests that the number of treatments is more important than the time period in which the treatments are obtained.

Discussion and conclusions

In both the current child and adult cognitive studies, there were clear improvements in cognitive performance in both HBOT populations over brain injured controls and normal controls. The HBOT patients not only improved but improved as a greater rate than the normals on almost all measures, indicating that this was not just a test–retest effect.

These results are very supportive of the use of HBOT in the treatment of chronic brain injury. These results are similar to those of Zhang et al. [5], expanding them to children and demonstrating actual changes in brain metabolism as well. They partially confirm the results of Hardy et al. [4], who found that there was improvement on their measures, but failed to find a difference between the experimental and the sham control group.

The Hardy et al. [4] study differed from the current study in several important ways: their sham control group was actually an HBOT treatment group although they used room air under pressure (rather than 100% oxygen) and they used more complex neuropsychological measures in the children. Whether their sham control group was actually a treatment group cannot be determined at this point but is an issue for future research. However, the use of more complex neuropsychological measures is an important issue. They found that one-third of their original sample had to be discarded because they could not complete the tests. The present researcher attempted a similar study with tests analogous to those used in the adult study. It was found that administering the tests to these children was frequently impossible and that the results were inconsistent due to attentional, focusing, physical, and fatigue factors even when testing could be completed which caused the results to be invalid. The current study using the Vineland was adopted in the face of these findings. Thus, the measures used by Hardy et al. [4] may contain too much random error to detect actual changes as was done using the more easily administered and evaluated Vineland measures.

One of the more interesting results of this study may be the absence of a dose–response curve in the child cognitive measures although it was found in both the adult cognitive measures and the SPECT measures in both children and adults.

Clearly, splitting the group into responders and non-responders suggested that this may reflect a differential response in some subpopulations. This may reflect differences related to area of injury, severity of injury, or specific type of pathology. Although most of these children were classified as Cerebral Palsy, this is a broad diagnosis which actually had many different etiologies which can be genetic, traumatic, metabolic, or any other cause of child brain dysfunction. Whether these factors play a role cannot be determined by this data, however. It is interesting to note that the adults in the study all were individuals with normal functioning who were injured by trauma or stroke. In this sample, the expected dose – response relationship was found. This could be interpreted to suggest that individuals with acquired injuries in an otherwise normal brain are more likely to respond than individuals with more generalized brain injury due to genetic or early metabolic disorders.

Another important possibility arising from this research along with the prior research is that cognitive changes appear more rapidly, becoming evident much earlier in the course of treatment than changes in objective SPECT scan scores. In the previous study [6], SPECT changes after 30 – 40 treatments in this population over a month were statistically borderline at best (although the blood flow measures increased overall), while the cognitive changes for a similar number of treatments were much more evident and easier to confirm statistically. Blood flow changes which were more evident after 2 months of treatment. This may indicate that the cognitive systems responds earlier, likely due to improvements in attention, concentration, and focusing which allow skills which were previously present but unexpressed to be more clearly measured and documented as these basic functions improve. However, despite these positive results, it should be remembered that only volunteers who were paying for their own treatment were included in the study and that neither the client nor the physician was blind to the intent of the treatment.

These findings may be especially significant in that all of the patients had chronic brain injuries and were at a plateau in terms of adaptive functions despite ongoing rehabilitation efforts. Such individuals would not be expected to spontaneously change because of physiological or behavioral improvement. Although these subjects were volunteers interested in the treatment, they had failed to make significant progress with other treatments they had voluntarily undertaken. This is true in both the adult and children's groups where individuals turned to HBOT only after failing to continue to progress with more traditional treatments.

Splitting the group into responders and non-responders suggested that this may reflect a differential response in some subpopulations. This may reflect differences related to area of injury, severity of injury, or specific type of pathology. This needs to be studied in detail to see if there are any physiological measures or markers derived from the type or location of injury which would help predict who will be a responder. The current results themselves suggest that early cognitive response after 20 treatments may itself be a predictor which would allow short term trial of patients to suggest who should be given more treatments. This is a critical area of future study, only volunteers who were paying for their own treatment were included in the study. Neither the client nor the physician was blind to the intent of the treatment. For the SPECT study [6] this is an unlikely cause of the results, but could be an issue for the cognitive testing.

In future studies, a more formal child battery would be of great importance. To truly test the neuropsychological (cognitive) improvement of these children there must be a valid form of direct testing. By relying on the parents' observations every study is limited. The problem with a cognitive test designed for these children is that most of them are nonverbal and operating on a preschool level. There is the issue of attentiveness and easy irritation, especially in children diagnosed with autism and cerebral palsy. So, for now these studies are limited by the means they use to test the improvement of the children.

There is a need to study the degree to which the factors of higher pressure and higher oxygen levels are responsible for the effects seen in this study. The initial emphasis has been to show that the therapy can work. Now we must determine if it the higher oxygen levels or the higher pressure or a combination of the two is responsible for the effects seen here. It may be that a less expensive but effective treatment can be derived which relies on lower oxygen levels or lower pressure. The researcher is working on the design and implementation of such studies at present.

While HBOT cannot cure a chronic brain injury, it can clearly be a help to a wide range of diagnosis. There needs to be intense research as to the effectiveness of HBOT in different sub-populations of brain injury. This needs to also include studying how HBOT and traditional therapies interact in increasing the overall recovery of the client. However, the results in these three studies are very supportive of the use of HBOT.

Given the widespread incidence of brain injuries and brain diseases in the population (especially as the population ages), the potential applications are numerous. The applications to dementias, for example, in which HBOT may be used to slow down the degeneration of the brain. The success of the treatment with chronic brain injury suggests that the treatment may be used with acute cases as well. In such cases, HBOT may be used not only to try to ameliorate the effects of a brain injury but to help the brain heal during the acute reorganization which follows a brain injury. If neurons can be stopped from dying, the patient may not develop the chronic symptoms which we now see. The potential for such research is clearly indicated by the current results.

Limitations

There are clear limitations to this type of clinical, non-blinded study. The absence of a clear sham HBOT treatment group is an issue as it could be that there was a significant placebo effect, but it should be noted that the brain injured clients in both groups were receiving more traditional cognitive, educational, and physical treatments and were being evaluated for the success of those programs when the data was collected. Thus, there was likely some placebo effects in both of the brain injured groups, but the authors acknowledge that such effects were likely to be greater in the HBOT group, especially in the parent ratings. This is less likely in the adult sample where the therapy was generally instigated by the caregiver rather than by the client.

The role of parental bias is difficult to quantify. Unfortunately, the level of the children's performance precluded the use of traditional standardized cognitive tests. The prior SPECT study provided evidence that metabolic changes are occurring, which supports the findings of this study where SPECT scans were not available on enough of the volunteers. It would obviously be ideal to have a study where all measures were completed on all subjects.

Although these subjects were volunteers interested in the treatment, they had failed to make significant progress with other treatment they had voluntarily undertaken. This is true in both the adult and children's groups where individuals turned to HBOT only after the failure of the more traditional treatments. These individuals would be expected to be less likely to show spontaneous improvement but this does not prevent 'wishful thinking' on the parent's part. Anecdotally, many of these low performing clients made clear gains in motor and communication skills which were evident to the research staff.

It can also be argued that the HBOT groups had more 'room' to improve because they performed lower at the beginning of the test period. One issue related to this concern is the presence of a ceiling effect on the tests. In both the child and adult brain injured groups, ceiling was not an issue although it was for some of the normals who performed as expected at a much higher level than the brain injured groups. However, spontaneous improvement because of the client's initial low level is less likely as the subjects all had chronic disorders which had not responded to treatment for a substantial time. There were no subjects included whose disorders were acute or who were improving on their own. It should be noted that the results in this group do not allow us to generalize to higher functioning individuals with milder chronic disorders.

Another related issue was retest effects. In the brain injured samples, this was controlled by having a non-HBOT brain injured treatment group. In most cases, the lower functioning client's memory problems were so significant that there was little likelihood of significant retest effects. There was also minor improvement in the normals, reflected by the basic nature of the skills measured and to some degree by a ceiling effect.

Overall, issues of this kind cannot be fully settled by this study. The ideal study would unquestionably be a double blind study with a sham HBOT group in which oxygen levels were controlled in the sham group by raising the pressure but lowering the level of oxygen. Such a study would be very difficult to do as a pure double blind since supervising technicians, for safety and for monitoring reasons, would need to know what levels of oxygen and pressure were in the chamber. It would be easier to have evaluators and families blind to the condition so as to minimize bias, but such a study cannot be completed in a clinical environment as was done here. Examiners were aware that each client was receiving some type of treatment and would have expected or at least desired improvement in subjects in both the HBOT and non-HBOT brain injured group. As noted earlier, parental biases could also play a role in reporting the child's behaviors. Despite these limitations, the results suggest that HBOT has a strong potential in these populations. More research is needed, and it is hoped that such research will be stimulated as the result of studies like this.

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