• DISCUSSION

- Cerebral palsy is generally considered as a nonprogressive condition resulting from neurological injury in the antenatal or perinatal period. Perinatal hypoxic-ischemic events resulting in cellular necrosis, neuronal inactivation and cerebral white matter injury are the most common causes of severe neurological handicaps in children with CP. [84]
- The aim of the current study is to assess the effect of the HBOT on group I (50 cerebral palsy patient who received 40 HBOT sessions, in addition to their conventional rehabilitation program), compared with group II (25 patients who received conventional rehabilitation program only).
- There was no statistical significant difference between both groups regarding the age range, it was 1.5 - 11 years among group I with a mean age of 4.85 ± 2.56 years and 1.5-12 years among group II with a mean age of 4.84 ± 3.04 years this comes in accordance with the study done by Collet, in which the age group range was 3 - 12 years. [85]
- Male to female ratio was 29:21 among group I and 13:12 among group II with male predominance 58% among group I and 52% among group II, that comes in accordance with the study done by Serdaroğlu A. in which 58.8% were males and 41.2% were females, with a male to female ratio 1.4:1. [86]
- Sundrum, mentioned that a strong association was observed between socioeconomic status and the risk of CP. [87] And in the current study 82% and 80% of the group I and group II respectively were from rural origin while 18% and 20% were urban. Odding E. mentioned that the prevalence of CP is higher in areas of low socioeconomic status. [88]

- Reddihough DS. mentioned that problems during labor such as obstructed labour, antepartum hemorrhage or cord prolapse may compromise the blood flow to the foetal brain causing hypoxia which may increase the incidence of CP. [89] In the current study 26% of group I and 32% of the group II suffered from obstructed labor.

- Of the group I 16% and 20% of group II had preterm labor this runs in agreement with the results published by Florence Livinec who reported increased risk of CP among preterm infants. [90]
- It was also reported that postnatal hypoxic ischaemic insult is an important cause of cerebral infarction. [91] Regarding the current study 92% of both groups reported a history of postnatal hypoxia.
- Subcommittee on hyperbilirubinaemia, American Academy of Pediatrics stated that late sequelae of kernicterus include, sensory neural hearing loss, CP and Chorioathetosis.[92] Of group I 14% and 16% of group II had a history of prolonged neonatal jaundice (more than 14 days in full term infants and more than 21 days in preterm infants).
- Among the current studied patients 64% of group I and 68% of group II reported that they were receiving epilepsy treatment. Carlsson M. also mentioned that 65% of CP patients had associated epilepsy; these children were at high risk for seizures because the brain damage and scarring can create abnormal electrical activity. [93]
- Visual problems like refractive errors, squint, squint with amblyopia, visual field defects, nystagmus, amblyopia, gaze palsies, optic nerve atrophy and ptosis have

been reported by Schacat WS. [94] Of group I 18% and 12% of group II reported variable forms of visual problems.

- Sander R. mentioned that the prevalence of auditory problems among his CP sample was about 15% either conductive or sensory neural, [95] while in the current study the percentage was 12% of group I and 8% of group II.
- It was reported that cognitive impairments found in about two thirds of CP cases, which leads to, distractibility, working memory impairment, mental retardation and learning disability. [24] The prevalence of moderate, severe and profound mental retardation is 30% to 65% of CP while the rest have mild impairment. [96] In the current study 48% of group I and 52% of group II suffered from different degrees of cognitive impairments.
- Among group I 46% of children who suffered from cognitive impairment, their parents and caregivers reported variable degrees of improvement in the form of visual working memory, auditory attention, self-control and awareness, increase the eye contact span and increase the number of spoken meaningful words. The improvement of cognitive function as an effect of HBOT in cerebral palsy was also reported by Collet. [85]
- This improvement may be due to the effect of HBOT on the global function of the brain beside its important role in improving motor functions, this comes in accordance with Carole S. who reported that more than 80% of parents reported cognitive and language improvement. [97] Cognitive improvement may be also attributed to the increased oxygenation of the brain tissue and increased muscular flexibility which may improve their overall ability to concentrate. [98] In the current study we may also attribute the cognitive improvement in addition to the above mentioned causes to the improvement in the sleeping pattern which allows a chance for better concentration.
- Drooling is a common problem affecting about 58% of children with CP,[99] regarding the current study the percentage of drooling among group I was 44% and 40% among group II.
- Drooling may be distressing for children as well as for their parents and caregivers. The consequences of drooling include risk of social rejection, damp and soiled clothes, unpleasant odour, irritated chapped skin, mouth infections, dehydration, interference with speech and social isolation. Drooling is generally not considered to be due to excessive production of saliva, it is more commonly associated with dysfunction of the oral phase of swallowing with inadequate lip closure, disorganised tongue movements exacerbated by lack of oral and perioral sensory perception, head-down posture, reduced frequency of swallowing and dysphagia. Of group I 64% had evident improvement after the treatment period. This improvement may be due to improvement of the cognitive functions, increased self awareness and may be also due to decreased spasticity of the neck muscles allowing a better head position. Marian S. also reported a decrease in drooling in CP children after HBOT sessions. [100]
- Sleep disorders are common in CP when compared with those with no chronic health conditions. Estimation of the prevalence of sleep disorders was ranging from 30-50%. Disorders of initiation and maintenance of sleep, excessive daytime somnolence and of arousal are common in CP. Sleep disorders are strongly associated with total body involvement in quadriplegic children, severe spasticity, active epilepsy and the use of antiepileptic drugs. It is also may be due central

causes related to the localization and extent of brain damage as the brainstem dysfunction. Disorders of initiation and maintenance of sleep may be also due to severe visual impairment or blindness. [39,101]

- In the current study 32% of group I and 24% of group II reported different forms of sleep disorders. Of group I 50% parents reported variable degrees of improvement of the sleep after the treatment period. Colonel James K. and Qibiao W. also reported improvement in sleep disturbance after HBOT sessions. This improvement may be due to the antispastic effect of the HBOT that permit the child to sleep, decrease of the epileptic activity, and may be also due to increased brain oxygenation. [102,103]
- It is known that physical therapy and rehabilitation programs are very important in improving function, quality of life as well as preventing and treating contracture due to spasticity in CP children. The current study was conducted to assess the beneficial effect of HBOT sessions when combined with the conventional rehabilitation program over the conventional rehabilitation program alone.
- As HBOT can initiate vascular repair and improve cerebral vascular flow, induce regeneration of axonal white matter, stimulate axonal growth, promote blood-brain barrier integrity and reduce inflammatory reactions as well as brain edema. [104] At the cellular level, HBOT can improve cellular metabolism, reduce apoptosis, alleviate oxidative stress and increase levels of neurotrophins and nitric oxide through enhancement of mitochondrial function in both neurons and glial cells and may even promote neurogenesis of endogenous neural stem cells. [105, 106]

- Cerebral palsy affects the whole body causing activity limitations and participation restrictions. [107] Respectable part of the problem is due to spasticity which interferes with function and activity of daily living, the current study assessed the antispastic effect of HBOT through MAS. Gross motor activity limitation is another part of the problem which was assessed by GMFCS while assessment of how the child uses his both hands was done by using MACS.
- Modified Ashworth Scale measures (MAS) the level of resistance to passive movement. It is effective in clinical practice because of its ease of applicability. This scale is widely used in research and has been highly investigated in many studies. [77]
- The Gross Motor Function Classification System (GMFCS) was developed to provide an objective classification of the patterns of motor disability in children with CP. The GMFCS was first conceptualised using data collected by the Gross Motor Function Measure (GMFM), and was later consensually validated by Palisano. [78, 79]
- The purpose of the Manual Ability Classification System (MACS) is to provide a systematic method to classify how children with CP use their hands when handling objects in daily activities. MACS is based upon self-initiated manual ability. The focus of MACS is on determining which level best represents the child's usual performance in home, school and community settings. Accordingly, the level must be determined by asking the parents or the caregiver. MACS does not intend to explain the underlying reasons for limitations of performance or to classify types of CP. Classification of a child should be made with reference to children of the same age. A child's motivation and cognitive ability influence their ability to handle objects and thereby their MACS level. [80]

- The Sensory Profile Caregiver Questionnaire is completed by the primary caregiver in order to gather information about the child's sensory processing abilities. [81] It is designed to measure the sensory processing abilities, help early intervention providers determine the impact of sensory processing and to help early intervention providers determine areas of strengths and concern related to intervention planning.
- And finally, observations were noticed by parents, caregivers and teachers that were not included in the assessment scales, they were able to document the changes and observations in their own words.
- In the current study there was a statistical significant difference in MAS between both groups according to before and after treatment period. This comes in accordance with Machado JJ, who reported that 95% of 230 CP children had reduced spasticity after receiving HBOT sessions. [108] Cordoba- Cabeza T. also reported the same regarding the 14 CP children assessed in his study. [109]
- Regarding GMFCS the statistical significant difference between both groups was supported by the study done by Montgomery D. [110] and Sethi A. who found a meaningful improvement of GMFM. [111]
- A statistical significant difference was also found between group I and group II regarding MACS. Hardy P. mentioned that HBOT improves the fine motor control. He also concluded that HBOT sessions improve gross motor function, fine motor control and reduce spasticity due to improvement of the function of the affected neural cells and attenuating the effect of hypoxia. [112]
- While regarding The Sensory Profile Caregiver Questionnaire there was no statistical significant difference between both groups.
- The current study showed that HBOT has a beneficial effect when combined with the rehabilitation program, this comes in accordance with Venter A. who reported that, the best results are achieved when HBOT coupled with appropriate physical therapy, as HBOT leads to increase in attention that is important for children to be aware of their environment in order to learn, which increase the effect of rehabilitation program. [113] Carole S. reported that most of the studies done to assess the role of HBOT in CP children have demonstrated significant and often impressive improvements compared with other therapeutic approaches for this condition. [97]
- A comparison was done to assess the results of group II before and after the treatment period (three months) and a statistical significant difference was found regarding MAS which may be attributed to the regular rehabilitation program day after day all through the treatment period and 88% of group II were receiving muscle relaxants (92% of group I were receiving muscle relaxants), while no significance was found regarding GMFCS and MACS.
- The effect of the HBOT though out the course of the sessions was assessed to detect if there is a statistical significant difference regarding the assessment scales over the session's time and to observe if 20 sessions are sufficient and there no additive effect for the other 20 session or there is an advantage of 40 sessions regimen over 20 sessions, and if the gained benefits lasts after the stoppage of the sessions.
- Mukherjee . [114] used the 40 sessions regimen. While Machado JJ. [108] and Cordoba- Cabeza [109] recommended the 20 sessions, And Waalkes P. did 80 sessions. [115]

- Concerning the MAS there was a statistical significant difference between before sessions assessment and after 20 sessions, statistical significant difference was also found between after 20 and after 40 sessions and there is no statistical significant difference between 40 sessions and one month later but the MAS mean continue to decrease despite of that.
- GMFCS showed a slight improvement after 20 sessions without statistical significant difference but the difference began to appear after 40 sessions and the statistical significant difference continued after stoppage of the sessions. The delay in response in motor improvement may be attributed to the spasticity as when the spasticity deceased after the first 20 sessions, patients started to gain motor functions in easier way and the progress continued after the stoppage of the sessions due to the continuation of the physical therapy program. This delay in improvement in GMFCS come in accordance with Shai Efrati , Eshel Ben-Jacob, who mentioned that weeks or months would be necessary for brain tissue regeneration and angiogenesis and they also reported that the brain of the CP child suffered from neurological insult since birth, so it will take time for the brain repair to become clinically apparent. [(84)]
- MACS shows statistical significant difference between before sessions assessment and after 20 sessions as well as between 20 and 40 sessions, but after one month assessment there was no significant difference, while the mean value continue to decrease.
- It was noticed that the clinical response of the younger candidates to the HBOT is better than the older ones, so group I was divided into two groups a younger age group -up to five years- group (I a) and an older one -more than five years- group (I b) in order to be able to analyze this observation and to kwon if a statistical significant difference between the response of both groups to the sessions will be found.
- Comparative assessment of both groups throughout the treatment course (before the sessions, after 20, 40 sessions and one month later) was done and statistically analyzed.
- The tables failed to show the difference between the two groups because there was no statistical significant difference between both groups but the line graphs shown in figures (13, 14) showed that the response in both groups was different and the younger group responded more rapidly and in a better way as regarding the three scales especially MAS.
- For further analysis a detailed comparison was done to detect if there was any statistical significance between both age groups regarding each scale throughout the treatment period (before sessions, after 20,40 sessions and one month later).
- And no statistical significant difference was found regarding the difference in response to HBOT sessions regarding MAS and GMFCS but the bar graphs shown in figures (15, 16) showed that there was a difference between both groups. Regarding MACS a statistical significant difference was found between before sessions assessment and after 20 sessions. Despite of that statistical significant difference was not found in after 20, after 40 and after one month assessments but the bar graphs shown in figure (17) showed that there was a difference between both groups. This finding may be explained by the time factor which affects the neurons and how long the ischemic penumbra can survive instead of the persistent hypoxia so the earlier the reoxygenation the better the outcome. On the other hand

the older age group has a greater chance for developing systemic complications and contractures which worsen the prognosis in general and also affect the response to the sessions.

- As every child has a different response to the treatment according to his unique circumstances; parents, caregivers and teachers was asked to report their special observations that were noticed during and after the treatment course. Some of the observations were documented by the parent's own words.
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SUMMARY

Cerebral palsy (CP) describes a permanent disorder of the development, movement causing activity limitation that is attributed to nonprogressive disturbances that occurred in the developing fetal or infant brain.

The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication, behavior, by epilepsy, and by secondary musculoskeletal problems.

Hyperbaric oxygen therapy (HBOT) is defined as the use of oxygen at greater than atmospheric pressure as a drug to treat basic pathophysiologic processes and the associated diseases.

CP is often caused by an ischemic/hypoxic injury during the perinatal period, this results in reduced blood flow and a major decrease in the supply of oxygen.

When breathing normobaric air at the sea level (760 mmHg, 1 ATA) hemoglobin in the blood is already 95% saturated with oxygen, with very little capacity for increasing oxygen transport. Oxygen is also dissolved directly in plasma in a more bioavailable form. According to Henry's Law, the absorption of gas is directly related to the partial pressure of the gas. About 17 times as much oxygen can be carried in the plasma when the patient breathes 100% oxygen at the pressure of 3 ATA compared with breathing room air at sea level.

This study was conducted to assess the effect of HBOT on cerebral palsy. Group I (50 patients) was assessed before starting the sessions, after 20, 40 sessions and one month after stopping the sessions. Group II (25 patients) was assessed before and after the treatment period. Both groups were assessed for each of the following:

6. Spasticity by Modified Ashworth's Scale (MAS).
7. Gross Motor Functional Classification System (GMFCS).
8. The Manual Ability Classification System (MACS) to assess the hand functions.
9. Sensory Profile Caregiver Questionnaire.
10. Global parent's assessment about their children.

There was no statistical significant difference between both groups regarding the age and sex, as well as the assessment parameters before treatment (MAS, GMFCS and MACS), while a statistical significance was found after treatment assessment regarding the assessment parameters.

There is statistical significant difference as regarding MAS(group I) comparing between before sessions and after 20 sessions assessment, also it shows statistical difference between after 20 sessions and after 40 sessions assessment while there is no statistical significance between after 40 sessions and one month after stoppage of the sessions.

As regarding GMFCS (group I) there was no statistical significance between before sessions assessment and after 20 sessions but there is statistical significance between after 20 sessions and after 40 sessions also between 40 sessions and one month later .

MACS (group I) shows statistical significance between before sessions assessment and after 20 sessions assessment and also between after 20 and 40 session but there was no statistical significance between after 40 sessions assessment and after one month.

There is no statistical significance between before and after sessions according to the sensory profile caregiver questionnaire in both groups.

There was a recorded improvement considering the cognitive problems, drooling and sleep disturbance among group one.

From the results of this study we concluded that, HBOT sessions has a positive effect on cerebral palsy children regarding the all the assessment scales used in the current study, spasticity was decreased which was assessed by MAS, gross motor movements was improved assessed by GMFCS and the hand functions also was improved assessed by MACS.

CONCLUSIONS

From the results of this study we concluded that:

- HBOT sessions have a positive effect on CP children especially when combined with the proper physical and medical treatment regimens.
- Spasticity was decreased as assessed by MAS.
- Gross motor functions were improved as assessed by GMFCS.
- The hand functions also were improved as assessed by MACS.
- Improvement of cognitive impairment, drooling and sleep disturbances were recorded.
- The 40 sessions regimen had an advantage over the 20 sessions regimen.
- The effect of HBOT persisted for one month after the cessation of the treatment.
- The beneficial effects of the sessions were more evident among the younger age group.