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Retrospective Study

Bilateral Staged Primary Total Knee Arthroplasty: Are Patients Less Pleased with their Second Side?

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ABSTRACT

Background

The available literature on the reported patient satisfaction following bilateral staged primary total knee arthroplasty (TKA) is limited. The purpose of our study is to compare patient-reported satisfaction following bilateral non-simultaneous TKA performed in a single unit.

Methods

We retrospectively analyzed our regional database, the Trent and Wales Arthroplasty Audit Group (TWAAG). Patients who had bilateral staged TKA in the University Hospitals of Leicester, UK, between 1990 and 2007 and had completed a 12-month post-operative questionnaire were included in the study.

Results

One thousand one patients were included in the study. 824 patients (82.3%) reported being satisfied with both of their primary TKAs. 91% and 88% reported being satisfied with their TKA respectively for the first and second sides. A chi-squared test revealed that the difference in satisfaction rates between the first and second side TKA was statistically significant. 86 patients were pleased with their first side but not pleased/unsure with the second side. On the other hand, 55 patients were pleased with their second side but not pleased/unsure with the first side. This difference was also statistically significant.

Conclusion

In our study, more patients were pleased following their first side compared to their second side TKA.

Keywords

Bilateral total knee replacement; Bilateral staged total knee arthroplasty (TKA); Patient satisfaction.

INTRODUCTION

Total knee arthroplasty (TKA) is a widely accepted treatment for patients with end-stage degenerative and inflammatory arthritis. Patient-reported satisfaction following surgery is an important outcome measure following TKA.[1-15] The reported patient-reported satisfaction following TKA in the literature varies, however current literature suggests that up to 20% of patients are not satisfied with their outcomes following this surgery.[3,10,13-14] Failure to meet patient expectation is one of the most important factors in patient dissatisfaction following surgery.[4,9,11,15-16] Hepinstall et al,[17] has demonstrated that amongst the different pre-operative contributors to TKA expectations, a history of a previous joint arthroplasty was associated with significantly lower expectations as compared to patients without a prior joint arthroplasty.

On the other hand, the currently available literature on the outcomes for bilateral staged TKA has little focus on patient reported satisfaction following surgery and the available limited literature on patient reported satisfaction is contradictory. In a retrospective study of 668 staged bilateral TKA,[18] the authors defined a minimal clinically important improvement (MCII) as an improvement in the Oxford Knee Scores of more than five points if achieved one year after their TKA and found that the outcomes following the second side TKA were inferior to the first side. In their study, 87.6% of patients achieved MCII following their second TKA as compared to 92.7% following their first TKA, the difference of which was statistically significant (*p*= 0.002). The outcome of the second side TKA in their study was independent of the time interval between the staged bilateral TKA. In another study,[19] the authors retrospectively compared 93 patients with bilateral staged TKA with different time intervals between the stages and found that patient satisfaction was significantly better for the second TKA compared to the first TKA if the interval between the two TKA was between 24-26-months.

The aim of this study was to compare patient-reported satisfaction between the two sides in patients who underwent bilateral staged TKA. Considering the theory that having had a previous TKA which is usually on the more painful or more arthritic knee can lead to potential higher expectations for their second primary TKA, we hypothesized that patients will report a lower satisfaction rate following their second side staged TKA.

PATIENTS AND METHODS

We performed a retrospective analysis of prospectively collected data from our regional joint register, the Trent and Wales arthroplasty audit group (TWAAG). The TWAAG database provided demographic and procedure related information on patients who had TKA in the Trent and Wales regions and included patients' BMI, the level of operating surgeons (Consultant, Registrar, Others including staff grade surgeons), type of implant used (PFC-CR; DePuy, PFC-PS; Depuy, Nexgen-CR; Zimmer, Nexgen-PS; Zimmer and PCA Stryker), whether or not patella resurfacing was also performed, intra-operative complications.

A standardized validated[20] questionnaire (Appendix 1) which included a question on their satisfaction (pleased, not pleased or unsure) was posted to all patients 12-months postoperatively. Patients who had undergone bilateral staged TKA between 1990 and 2007 in Leicester and responded to their post-operative questionnaire were included in the study and a retrospective analysis of the collected data was performed. We excluded patients in whom the satisfaction question was not completed for one or both sides.

Statistical analysis was performed using the two-tailed fisher exact test and chi-square tests for our analysis.

RESULTS

A total of 1001 patients (542 female, 459 male) were included in this study. The mean age patients at the time of the first side TKA was 68.7 years (SD=8.3 years) and the mean age for the second side TKA was 71.4 years (SD=7.9 years). The average time gap between the first and second TKA in the sample was 780-days, ranging from 2-days to 5317-days. From 1001 patients who underwent their first side TKA, 910 patients (91%) reported to be pleased and 91 patients (9.1%) were either not pleased or unsure about their satisfaction (37 patients were not pleased and 54 patients were unsure). For the second side TKA, 879 patients (88%) reported to be pleased with their TKA, and 122 patients (12%) were either not pleased or unsure about their satisfaction following their second side TKA (54 patients were not pleased and 68 patients were unsure). A chi-squared two-tailed test was performed which revealed a statistically significant difference in the patient-reported satisfaction between the two sides (*p*=0.025).

From 1001 patients, 86 patients (8.6%) were only satisfied with their first side TKA and 55 patients (5.5%) were only satisfied with their second side TKA. Fisher exact test revealed that this difference was also statistically significant (*p*=0.014).

From 1001 patients, 824 patients (82.3%) reported being satisfied with both of their primary TKAs. Eleven patients (1%) were not satisfied with both sides and 14 patients (1.4%) were unsure about their satisfaction following both side TKAs. Therefore, 849 patients (85%) reported similar satisfaction/pleasure following their knee replacement for both sides. The remaining 152 patients (15%) had different satisfaction/pleasure reports between the two sides.

Table 1 shows the breakdown of patient-reported satisfaction following their staged bilateral TKA.

Table 1. *Patient-reported Satisfaction Following Bilateral Staged TKA. Number and Percentage of Patient Satisfaction Report*

Patient-reported satisfaction following bilateral staged TKA	Number	Percentage
Pleased with both side TKA	824	82.3%
Not pleased with both side TKA	11	1%
Unsure about both side TKA	14	1.4%
Pleased with first side only (Not pleased/unsure with second side)	86	0.86%
Pleased with second side only (Not pleased/unsure with second side)	55	0.55%
Unsure about their first side and not pleased with the contralateral side	5	0.5%
Not pleased with their first side and unsure about contralateral side	6	0.6%
Total	1001	100%

DISCUSSION

Although there has been a lot of focus on patient-reported satisfaction as one of the important patient-reported outcome measures (PROMS) for unilateral TKA,[1-15,21] there is a paucity of evidence on patient-reported satisfaction following bilateral staged TKA. Amongst various factors which can influence patient-reported satisfaction after TKA, patients' previous experience of a contralateral TKA can affect theirs after their next TKA, which could reflect on their reported satisfaction following their second TKA. Although one could expect that the previous experience of the whole process of pre-operative, operative and post-operative period, should provide the patients with better understanding and more realistic expectations, which could reflect as a higher satisfaction following their second side TKA, this is not always seen in practice.

We have retrospectively analyzed a prospectively collected regional arthroplasty database (TWAAG). We evaluated the patient-reported satisfaction in 1001 patients who had undergone bilateral staged TKA in Leicester. Our findings have shown that although patient-reported satisfaction one year after each TKA, was relatively high considering the current standards (90.9% after the first side and 88% after the second TKA), a larger proportion of patients did not report to be pleased with their second side TKA the difference of which is statistically significant (p=0.025). Also amongst the patients whom only reported to be pleased with one of the two sides TKA, a larger proportion was pleased with their first side TKA (86% *vs*. 55%) which was again statistically significant (p=0.014).

We acknowledge that this study has several limitations. Firstly, although our study is relatively large numbered, considering the fact that patient-reported satisfaction is a multifactorial outcome, a higher number of patients would have added to the validity of this study. Secondly, we did not specifically look for post-operative complications after each TKA, which could affect patient-reported satisfaction. However, as part of the TWAAG form, intra-operative complications were recorded and there were no documented intra operative complications for any of these patients on the database. We found a total number of 19 patients who had revision surgery for different reasons from which there were 10 cases for the first side and 9 cases for the second side. These patients were not excluded from our study as they were almost equally distributed.

Finally, we did not specifically analyze the discrepancies in relation to the degree of surgeons and whether or not patella resurfacing was performed. Although the majority of cases were performed by consultants or associate specialists, as expected, in a University Teaching Hospital, Registrars and Fellows would perform supervised primary TKA. A study from 2018,[22] has shown equivalent functional outcomes with no difference the post operative range of movement, operative time, length of stay or transfusion rates between primary TKA performed by supervised registrars and consultants. With regards to patella resurfacing, the vast majority of primary TKA performed in our unit were without patellar resurfacing. This is due to the fact that most level 1 randomized trial and subsequent meta-analyses have not shown a statistically significant difference in functional outcomes, knee scores, patient satisfaction, and anterior knee pain.[23-26]

CONCLUSION

We have presented a relatively large numbered study specifically analyzing patient-reported satisfaction following bilateral staged TKA from our regional joint arthroplasty registry. We have shown that in our study, patients have reported a lower satisfaction rate following their second side primary TKA compared to the first side primary TKA. This information can improve patient counseling during the pre-operative period with a view to providing a more realistic expectation prior to surgery. We hope that this study would encourage larger numbered studies particularly from large databases such as national joint registries.

ETHICS, REGISTRATION, FUNDING AND CONFLICTS OF INTEREST

All of the patients in the TWAAG dataset had given formal written consent for the use of their data for research purposes at the beginning of the data collection process. Although ethical approval had been granted for utilizing the dataset for research purposes by the Leicester University Ethics Committee, this project was separately enrolled as a service evaluation project to university hospitals of the Leicester Audit and Development Department. Our electronic database was password encrypted and anonymous to patients and operating surgeons.

There was no internal and external funding provided for this study and none of the authors had any personal or financial interest in the project.

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APPENDIX

Appendix 1. *Sample of TWAAG Questionnaire which was Sent to all Patients 12-months after their Primary TKR*

<<NUMBER>>/<<TITLE>><<FORENAME>> <<SURNAME>>				
THESE QUESTIONS APPLY TO YOUR <<SIDE>> <<HIPKNEE>> REPLACEMENT. PLEASE CIRCLE THE ANSWER WHICH IS NEAREST TO HOW YOU FEEL				
1) Are you pleased with the result?		YES	NO	UNSURE
If you are not pleased, can you identify the reason why in the space below-				
2) Do you have pain?	BAD	SOMETIMES	RARELY	NEVER
3) Do you walk outside?	OFTEN	SOMETIMES	RARELY	NEVER
4) Have you had to go to your doctor about your joint replacement?			YES	NOs
5) Are you still being seen at hospital by your surgeon?			YES	NO
6) Has there been any complication with your joint replacement? If yes, please state the complication below-			YES	NO
7) Have you had another operation on THIS joint replacement? If yes, please state what the operation involved below-			YES	NO
8) If you have experienced any problems with your <<SIDE>><<HIPKNEE>> that your surgeon is unaware of, would you like us to contact them on your behalf?			YES	NO
9) Please feel free to comment about any aspect of your joint replacement below.				

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Review

Muscle Cell Function and the Effects of Hyperbaric Oxygen Therapy

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ABSTRACT

There are different processes *via* which a muscle cell can utilize oxygen to make energy that will sustain activity. The type of activity and duration of activity will determine what energy system is used to sustain the activity being done. Aerobic metabolism uses oxygen to sustain the energy demand. Oxygen is obtained from the air we breathe, and then transported to the cells though the myoglobin. Although ambient air only contains 21% oxygen, it is enough to sustain life and energy needs. But what if the muscle cell could instead receive 100% oxygen? The delivery method would be *via* hyperbaric oxygen therapy (HBO) which supplies oxygen at 100% concentration under a minimum of 1 atmospheric pressure. Atmospheric pressure will affect the outcomes of consuming 100% oxygen. Research supports positive findings on oxygen therapy under pressure and muscle cell recovery but much research still needs to be investigated. One research study revealed detrimental effects of 100% oxygen breathed in consistently for days resulting in comorbidities that did not exist prior to experiment. HBO can pose some risks but if it is applied in a controlled manner, HBO can be a safe option to enhance cellular recovery and cell function.

Keywords
Oxygen; Hyperbaric oxygen therapy; Muscle recovery; Muscle cells; Pure oxygen.

MUSCLE CELL FUNCTION AND THE EFFECTS OF HYPERBARIC OXYGEN THERAPY

The ambient air we breathe in contains only 21% oxygen; the air is not 'just' oxygen. It contains typically 78% nitrogen, 21% oxygen and the 1% remaining is a blend of carbon, helium, argon and hydrogen. As an interesting fact, the 1% are gasses that surround the earth and the closer to sea level we are breathing, the higher the percentage of oxygen. Other factors affect ambient air as well such as the pollution level. In a general statement, what we do as humans: manufacturing processes, transportation and chemicals we use, etc., affect the quality of the air we breathe. What if instead of decreasing air quality with our modernization efforts, we increase our breathing air quality by increasing the purity and concentration of oxygen we take in? What would the effect of taking in 100% oxygen do? Would muscles work better, heal faster? After all, is not more better?[1]

HOW MUSCLE CELLS WORK

Muscle fiber contractions depend on excitation-contraction (EC) coupling and occur in a sequence of events. EC coupling in its simplistic form is an action potential that triggers a myocyte to contract, followed by subsequent relaxation. This is where the muscle cell filaments slide along each other, expanding and contracting the cell. The sarcoplasmic reticulum (SR) is a membrane structure found not only within muscle cells but it also resembles SR in other cells where its main function is to store the calcium ions needed for muscle cell functions including but not limited to manufacturing secreted proteins, integrating proteins in the cell membrane and facilitating glycosylation. The calcium ions regulate muscle contractions by allowing them to occur. The SR is a noteworthy structure in that it contains large amounts of myoglobin (a protein that assists in oxygen-binding and is found in red blood cells). This makes the blood the ideal oxygen transport system to the cells once the oxygen supply has been replenished from respiration.[2]

PURPOSE OF OXYGEN

The purpose of oxygen in the human body lies within each cell. Oxygen is used by each cell to assist in the process of converting stored energy that is stored in food to a useable form, referred to as cellular respiration, through a reaction with glucose. The purpose of this process is to power the cells, produce involuntary movements and move materials into and out of cells.[3] The body has three major phases of cellular respiration: glycolysis (removes the hydrogen atoms by redox), the citric acid cycle (also known as the Krebs Cycle) and the electron transport system (ETS). The processes are always occurring as the body cells typically have a short life span and constantly degrade and rebuild an essential process for all biochemical reactions in the body. The human body has unending energy needs due to cellular metabolism being an ongoing process.[4]

GLYCOLYSIS AND CELLULAR RESPIRATION

The first process that occurs in cellular respiration is referred to as glycolysis and although this stage of anaerobic respiration can occur without oxygen, the process cannot continue without the assistance of oxygen. Oxygen is a vital component of human life. Lack of oxygen or insufficient amounts will initially impair function of the cells and eventually lead to cellular death followed by death of the host if adequate levels are not restored to functional capacity in a timely manner. Using oxygen for cellular respiration is referred to as glycolysis or aerobic respiration (meaning "with air"). The body uses oxygen and combines it with stored energy to convert it to a useable form by combining with glucose. Respiration without the use of oxygen is referred to as anaerobic respiration (meaning "without air"). How glycolysis gets produced will be very different depending on whether or not oxygen was used and if there was enough available to sustain the energy conversion process. If there was enough oxygen available to complete glycolysis at the time it was needed, the end product will be pyruvate. Pyruvate is a transport molecule that is needed to carry carbon atoms into the mitochondria to be oxidized to carbon dioxide and water (cellular waste). It then becomes part of the citric acid cycle (which occurs in the mitochondria of eukaryotic cells) and the process aerobically metabolizes carbohydrates, fats and proteins. This is where the cellular waste gets produced. The waste products of the process are the conversion of adenosine diphosphate (ADP) to adenosine triphosphate (ATP). ATP is the biochemical energy carrier for all living cells to store and use energy. If there was not enough oxygen to make energy readily available to sustain an activity level and the body's processes are requiring the energy, the end product will be lactate.[5]

Let's look at a functional application of how this applies in the muscle cell. When a runner is sprinting a very short distance, initially the muscle cells will use the stored ATP and movement is sustained from this energy source for about 3-seconds. The next phase begins where molecules are broken down and rebuilt for quick energy. This whole energy conversion process occurs very quickly and can support the body's activity for about 8-10 seconds. Should the demand for energy continue based on continual need for oxygen to sustain energy production, the next sequential muscle cell energy acquisition comes from the anaerobic process and produces lactic acid produced from ATP made from glucose, derived from cellular glycogen. ATP here is made at a much slower rate than the previous system. With energy needs still in high demand, by the two-minute mark of sustained motion, oxygen is added to the ATP production process and this allows glucose to be completely broken down into carbon dioxide and water (waste products of aerobic energy synthesis). This is aerobic respiration. The aerobic system produces ATP the slowest but can sustain activity for the longest amount of time.

We have shown how the body uses and needs oxygen. As discussed prior, the ambient air we breathe is made up of only 21% oxygen. Wouldn't more be better? After all, with more oxygen surely the efficiency of the muscle cell will increase, effectively enabling us to sustain an improved activity level or even recover better through increased cellular function? The answer isn't that simple.

In a study that examined guinea pigs breathing 100% oxygen at normal pressure for 48-hours, the results revealed that damage had occurred *via* fluid accumulation in the lungs and to the epithelial cells lining the alveoli as well as damage occurring to the pulmonary capillaries.[6] Studies reveals that humans breathing 100% oxygen at normal pressure will experience:

- Fluid in the lungs
- Reduced rate of gas flow across the alveoli resulting in an increased effort to breathe to get enough oxygen
- Chest pains with deep breathing
- Total volume of exchangeable air in the lungs decreases by 17%
- Mucus plugs local areas of collapsed alveoli (atelectasis)

From the results from this study, we see that consuming 100% oxygen has very detrimental effects on the body.

APPLICATION OF 100 PERCENT OXYGEN

Other factors come in to play as well with increased oxygen concentration consumption such as atmospheric pressure. The effects of breathing 100% oxygen change when atmospheric pressure changes. The study mentioned above looked at 100% oxygen consumed at 'normal' pressure (undefined in the study). We breathe at about 1 atmospheric pressure (determined at sea level). Air has weight. One atmospheric pressure is equivalent to 14.7 pounds per square inch (psi).[6] This is the amount of pressure that is exerted on the body by the earth. Atmospheric pressure affects the lungs ability to breathe. For the lungs to be inflated, the pressure on the outside of the lungs must be greater than the pressure inside the lungs, this effectively fits the definition of diffusion. Then as we breathe, diffusion 'pushes' air into the lungs and also helps push oxygen across the membrane of the cells in the lungs.[7,8] There is an inverse relationship of altitude to atmospheric pressure; atmospheric pressure will decease as altitude increases. Breathing becomes more difficult the higher you go. In the body, at high altitudes, air molecules are spread farther apart due to the decreased ambient air pressure, making it harder for people to breathe from the lack of sufficient oxygen available to enter the lungs. As indicated on the web resource at Craig Hospital,[7] in Denver at an altitude of 5,280 feet, we breathe in 17% less oxygen than someone does at sea level and by 18,000 feet we breathe in 50% less oxygen. In the opposite direction, the deeper we go away from sea level, as in under the water, the pressure increases. Even at just a few feet below the water's surface, it becomes difficult to breath as the water pressure becomes too great for the breathing muscles to expand and contract.[6] Research has been established that the body can only withstand up to 3 to 4 atmospheres of pressure and there is also a minimum. We actually need some atmospheric pressure on the body for it to function properly (0.47 millibars of atmospheric pressure is the minimum, referred to as the Armstrong limit, as per the physician that discovered this, Dr H. Armstrong) and that the body's oxygen pressure at about 21% is enough to saturate hemoglobin. The point here is that atmospheric pressure effects the body's ability to manage oxygen which is an essential element for cell function.

If oxygen is administered under pressure (greater than ambient air), injuries may occur such as acute oxygen poisoning with symptoms of nausea, dizziness, muscle twitches, blurred vision and seizures/convulsions.[9] Consider diving as an example where divers breathe in atmospheric air at 21% oxygen under pressure from a tank while submersed at depth in water. The deeper the dive, the more pressure is placed on the lungs. We already know there is an inverse relationship of elevation to oxygen at atmospheric pressure but what about exposure to 100% oxygen under pressure at 3 times atmospheric pressure during controlled intervals such as in HBO (for about 1-2-hours) with infrequent applications of the treatment?

HYPERBARIC OXYGEN THERAPY

HBO therapy involves an outpatient treatment where the patient breathes 100% oxygen in a pressurized room or chamber at about three times normal atmospheric pressure. This enhances the body's capability to gather more oxygen. Research has shown that with controlled applications for specific conditions, this is an effective treatment including decompression sickness, serious infections, bubbles in the blood vessels and wounds that won't heal (from diabetes or a radiation injury).[10]

The difference between HBO causing extensive internal body damage and being therapeutic is when 100% oxygen is administered in a controlled environment under pressure. Another difference in causation between having detrimental or therapeutic outcomes is the length of time subjects were exposed to the 100% oxygen. In the studies using 100% oxygen over x amount of days was held as the constant variable in the studies. It is not logical or feasible to breathe 100% oxygen all day and every day at ambient atmospheric pressure, which is what Brain's[4] study on guinea pigs has shown to have the most extensive damage from use. Was all the resultant tissue damage from the 100% oxygen at atmospheric pressure in his study or was it from the constant extended use of taking in 100% oxygen, or a combination? This is an example of how the application of HBO therapy can have very different outcomes depending on the application and conditions applied to.

Therapeutic outcomes result from increased oxygen being carried through the blood which is made possible through the administration in an increased atmosphere/pressure climate within a defined schedule. The benefits can help to fight bacteria and stimulate the release of growth factors and stem cells which both promote healing.[10] Injured tissue requires an increased amount of oxygen to survive and HBO increases the amount of oxygen your blood can carry. When the increased oxygen reaches the cells, it helps restore blood gases and tissue function. This is what enhances the ability to fight infection and promote healing. Conditions that can be healed and have been identified with the use of HBO include:

- Anemia, severe
- Brain abscess
- Bubbles of air in your blood vessels (arterial gas embolism)
- Burn
- Decompression sickness
- Carbon monoxide poisoning
- Crushing injury
- Deafness, sudden
- Gangrene
- Infection of skin or bone that causes tissue death
- Nonhealing wounds, such as a diabetic foot ulcers
- Radiation injury
- Skin graft or skin flap at risk of tissue death
- Vision loss, sudden and painless

EFFECTS OF LUNG OXYGEN UPTAKE ON MUSCLE CELLS

Regarding metabolic properties of muscle cells with reference to sports, the contractile muscle and energy turnover/frequency during exercise varies at different speeds depending on the rate of eccentric contractions. In a study conducted by Gaesser & Brooks, 1975; Coast &Welch, 1985,[11] results demonstrated that pulmonary oxygen uptake does have a direct positive correlation to increased exercise rate. What remained unknown was whether the increased pulmonary oxygen uptake also effected the oxygen uptake of contracting muscles (and therefore muscle cells). To further explore the effect of enhanced oxygen availability on muscle cells, let's consider how it can be transported by blood in two ways: chemically, bound to hemoglobin, and physically, dissolved in plasma.[9] Oxygen binds to Hemoglobin by binding to an iron atom and then the oxygen saturated hemoglobin molecules carry the oxygen to the cells and carbon dioxide to the lungs. In a normal breathing environment, the body's normal hemoglobin has an oxygen saturation rate averaging around 97%. Consequently, during HBO, hemoglobin is also fully saturated on the venous side, and the result is an increased oxygen tension throughout the vascular bed. Since diffusion is driven by a difference in tension, oxygen will be forced further out into tissues from the vascular bed.[12] The short-term effects on the muscle cells from HBO therapy include vasoconstriction and enhanced oxygen delivery, reduction of edema, phagocytosis activation and an anti-inflammatory effect.[13] On the longer-term side, the benefits include neovascularization, osteogenesis and stimulation of collagen production by fibroblasts (great for wound healing and recovery from radiation injury).[12] Theoretically, as shown by research here, the answer to the researchers question that went unanswered in their study as to whether the increased pulmonary oxygen uptake also effected the oxygen uptake of contracting muscles (and thus muscle cells), the answer would be yes.

In studies conducted on humans where muscle soreness was purposefully induced and HBO therapy was strategically administered. Control groups were used in randomized, controlled, double-blind studies, the gold standard for research. The results from several studies all concluded that hyperbaric oxygen has an inhibitory effect on the inflammatory process, there was a significant recovery of eccentric torque but they also agreed despite this accelerated healing and there was no decrease in pain/discomfort from the delayed onset of muscle soreness (DOMS). In a similar study design to the above, it revealed a stimulation of aerobic oxidation to the mitochondria. This conclusion was supported by a similar study that revealed lactic acid and ammonia are removed more rapidly with the HBO treatment leading to a faster recovery time.

During the Nagano Winter Olympics, scientists used HBO as a recovery method for muscle fatigue. Athletes received HBO treatment for only 30-40-minutes (note the short duration time) and received up to a maximum of six treatments. The outcome showed that all athletes benefitted from the treatment as evidenced through faster recovery times.

CONCLUSION

Muscle cell metabolism has been shown to be enhanced by HBO. In some studies, HBO therapy lead to faster recovery times and supports oxygen saturation during hemoglobin transport to cells. Despite the positive cellular effects demonstrated through the research, a few studies had participants remain in discomfort with the effects of DOMS. This begs to question and encourage more research on enhanced positive cellular activity with improved muscle cell function and the negative effects of cellular breakdown and restructuring. Delivering 100% pure oxygen under 2-3 atmospheric pressure on a therapeutic schedule has shown positive results and with this application, injuries have been drastically reduced. Some further research studying the applications of the therapeutic administration would benefit this topic's next steps. Perhaps with varying daily frequency or application time, other conditions can be abetted. What about doing very light exercise while getting HBO 'treatment', what effect would that have?

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