Hyperbaric oxygen therapy for delayed onset muscle soreness and closed soft tissue injury

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A substantive amendment to this systematic review was last made on 30 June 2005. Cochrane reviews are regularly checked and updated if necessary.

Abstract

Background: Soft tissue injuries (including muscle damage after unaccustomed exercise) are common and are often associated with athletic activity. Hyperbaric oxygen therapy (HBOT) is the therapeutic administration of 100% oxygen at environmental pressures greater than one atmosphere.

Objective: To assess the benefits and harms of HBOT for treating soft tissue injury, including delayed onset muscle soreness (DOMS).

Search strategy: We searched the following in July 2004: CENTRAL, MEDLINE, EMBASE, CINAHL, DORCTIHM and reference lists from relevant articles. Relevant journals were handsearched and researchers in the field contacted.

Selection criteria: Randomised trials comparing the effect on closed soft tissue injury (including DOMS) of therapeutic regimens which include HBOT with those that exclude HBOT (with or without sham therapy).

Data collection and analysis: Four reviewers independently evaluated study quality and extracted data. Most of the data presented in the review were extracted from graphs in the trial reports.

Main results: Nine small trials involving 219 participants were included. Two trials compared HBOT versus sham therapy on acute closed soft tissue injuries (ankle sprain and medial collateral knee ligament injury respectively). The other seven trials examined the effect of HBOT on DOMS following eccentric exercise in unconditioned volunteers.All 32 participants of the ankle sprain trial returned to their normal activities. There were no significant differences between the two groups in time to recovery, functional outcomes, pain, or swelling. There was no difference between the two groups in knee function scores in the second acute injury trial; however, intention-to-treat analysis was not possible for this trial.Pooling of data from the seven DOMS trials showed significantly and consistently higher pain at 48 and 72 hours in the HBOT group (mean difference in pain score at 48 hours [0 to 10 worst pain] 0.88, 95% CI 0.09 to 1.67, P = 0.03) in trials where HBOT was started immediately. There were no differences between the two groups in longer-term pain scores or in any measures of swelling or muscle strength.No trial reported complications of HBOT but careful selection of participants was evident in most trials.

Reviewers' conclusions: There was insufficient evidence from comparisons tested within randomised controlled trials to establish the effects of HBOT on ankle sprain or acute knee ligament injury, or on experimentally induced DOMS. There was some evidence that HBOT may increase interim pain in DOMS. Any future use of HBOT for these injuries would need to have

been preceded by carefully conducted randomised controlled trials which have demonstrated effectiveness.

Background

Soft tissue injuries are common and range from minor abrasions and bruising to major disruption of tendons, ligaments and muscles. It is difficult to obtain accurate estimates of the impact on society of soft-tissue injuries taken in isolation, but injuries in general result in tens of millions of emergency room visits and cost hundreds of billions of healthcare dollars per annum in the USA alone (Finnegan 2003). Soft tissue injuries are commonly associated with athletic activity, and occur in both elite and recreational athletes. In both these groups, soft tissue injuries may be associated with considerable loss of work and health costs (Van Mechelen 1997). The causes of soft tissue injuries are diverse and may involve acute traumatic impact, repetitive strain and overuse, or muscle injury induced by unaccustomed exercise (Babul 2000a; Leach 1998). This review is restricted to acute closed injuries involving muscle, ligament and tendon only, and where the mechanism is unaccustomed use, trauma from a direct blow, strain or overuse injury.

Of particular interest in this review is the phenomenon of delayed onset muscle soreness (DOMS). Familiar to most individuals at some time, this is the name given to the syndrome of pain, swelling and stiffness in muscles in the days following a bout of unaccustomed activity in that muscle group. DOMS can exhibit as anything from minor muscle soreness to debilitating pain and swelling, but is most commonly described as causing a reduction in joint range of motion, shock attenuation and peak torque. A recent review confirms that the mechanisms, treatment strategies, and impact on athletic performance remain uncertain (Cheung 2003). Putative mechanisms include lactic acid accumulation, muscle spasms, connective tissue damage, inflammation and enzyme efflux secondary to muscle cell damage. DOMS is frequently used as an experimental soft tissue injury in human research because it is both self-limiting and reliably reproduced in individuals unaccustomed to exercise.

Accepted treatment methods vary greatly with the specific injury. They may, however, be classified broadly as rest, local measures to reduce oedema (e.g. massage, cryotherapy, elevation), drug therapy (typically non-steroidal anti-inflammatory agents), stretching or further exercise (particularly for delayed onset muscle soreness), surgical, and rehabilitative (Cheung 2003; Kader 2002; Perryman 2002). The ultimate aim of treatment is to restore pain free function and enable the return to activity in the shortest time compatible with a low risk of re-injury.

Hyperbaric oxygen therapy (HBOT) is the therapeutic administration of 100% oxygen at environmental pressures greater than one atmosphere absolute (ATA). Administration of HBOT involves placing the injured individual in an airtight vessel, increasing the pressure within that vessel, and administering 100% oxygen for respiration. In this way, it is possible to deliver a greatly increased partial pressure (supply) of oxygen to the tissues. Typically, treatments involve pressurisation to between 1.5 and 3.0 ATA for periods between 60 and 120 minutes once or twice daily.

HBOT is associated with some risk of adverse effects including damage to the ears, sinuses and lungs from the effects of pressure, temporary worsening of short-sightedness, claustrophobia and oxygen poisoning. Although serious adverse events are rare, HBOT cannot be regarded as benign.

It has been suggested since 1982 that HBOT might accelerate injury recovery (Oriani 1982). HBOT has been shown in a number of injury models to reduce oedema and preserve microcirculation through vasoconstriction with enhanced oxygen delivery, a direct osmotic effect and the inactivation of white cell adhesion (Hills 1999; Nylander 1985; Staples 1995; Thom 1994). The first clinical report, which appeared in 1993, described a 55% reduction in days lost

to injury by Scottish soccer players suffering from a variety of injuries following the application of HBOT (James 1993). Since then, a number of anecdotal reports in the non-medical media suggest that the use of HBOT has become commonplace in some elite sporting clubs. In addition, some comparative human trials have been published.

Given the increasing use of HBOT for soft tissue injury, and the uncertainty about the benefit and risks of this therapy, it is important to carry out a systematic review of the evidence.

Objectives

The aim of this review is to assess the evidence for the use of HBOT for the treatment of soft tissue injuries including DOMS. Specifically, we wish to address, does HBOT safely improve and speed-up functional outcome after injury?

Criteria for considering studies for this review

Types of studies

We considered any randomised or quasi-randomised (use of a method of allocating participants to a treatment that is not strictly random e.g. by date of birth or hospital record number) clinical trials that compared HBOT with no HBOT (no treatment or sham). We considered both trials that employed standard alternative therapies as the comparator, and those that compared HBOT to no treatment or sham alone.

Types of participants

Patients with DOMS following exercise or patients with closed injuries to tendon, ligament or muscle tissue, including repetitive strain injuries. No restrictions on age or gender were made.

Types of intervention

We accepted studies that compared treatment regimens including HBOT with similar regimens that excluded HBOT. Where co-interventions differed significantly between studies this was clearly stated and the implications discussed.

We accepted any standard HBOT regimen used for promoting recovery from soft tissue injury. Generally, a standard regimen involves HBOT administered in a compression chamber between pressures of 1.5 ATA and 3.0 ATA and treatment times between 30 minutes and 120 minutes on at least one occasion.

Types of outcome measures

Studies were eligible for inclusion if they reported any of the following outcome measures:

- Primary outcomes
- (1) Recovery defined as return to pre-injury level of activity (sports/work).
- (2) Rate of recovery (e.g. time to return to previous athletic activity).
- (3) Persistent pain (long-term).

- Secondary outcomes
- (4) Patient functional assessment measures.
- (5) Pain or swelling.
- (6) Objective measures of muscle strength, joint stability or similar.

- (7) Complications (including re-injury) and adverse effects of HBOT (visual disturbance; barotrauma - aural, sinus, pulmonary - and oxygen toxicity). Other recorded adverse effects as reported in the trials.

In addition, note was taken of reports of service utilisation or resource use; for instance, length of hospital stay and costs of HBOT.

Search strategy for identification of studies

See: Cochrane Bone, Joint and Muscle Trauma Group search strategy

We searched The Cochrane Musculoskeletal Injuries Group trials register (to July 2004), The Cochrane Central Register of Controlled Trials (The Cochrane Library July 2004), MEDLINE (1966 to July 2004), EMBASE (1980 to July 2004), CINAHL (1982 to July 2004), an additional database developed in our hyperbaric facility, The Database of Randomised Trials in Hyperbaric Medicine (Bennett 2003), and reference lists of articles.

A sensitive subject search strategy was combined with the optimum trial search strategy (Robinson 2002) for use in MEDLINE (OVID WEB) (seeTable 01) and modified for use in other databases.

- In addition we made a systematic search for relevant controlled trials in specific hyperbaric literature sources by:
- (1) contacting experts in the field and leading hyperbaric therapy centres (as identified by personal communication and searching the Internet) to ask for additional relevant data in terms of published or unpublished randomised trials,
- (2) handsearching relevant hyperbaric textbooks (Jain 1999; Kindwall 1999; Oriani 1996), journals (Undersea and Hyperbaric Medicine, Hyperbaric Medicine Review, South Pacific Underwater Medicine Society (SPUMS) Journal, European Journal of Hyperbaric Medicine and Aviation, Space and Environmental Medicine Journal) and conference proceedings (Undersea and Hyperbaric Medical Society, SPUMS, European Undersea and Baromedical Society, International Congress of Hyperbaric Medicine) published since 1980, and
- (3) contacting authors of relevant studies to request details of unpublished or ongoing investigations.

Methods of the review

- Data retrieval and management
- One author (MB) was responsible for hand searching and identification of eligible studies. Three authors (MB, JT and ML) examined the electronic search results and identified potentially eligible studies. Full reports of these studies were retrieved and reviewed independently for inclusion by four authors, two (MB, ML) of whom have content expertise with HBOT and two (JT, JB) with content expertise in orthopaedics. In addition, one of the authors (MB) has expertise in clinical epidemiology. Any differences were resolved by discussion. None of the authors were allocated to consider papers they had participated in as an author or where the paper was written by authors at the same institution. We recorded data using the data extraction form developed for this review. All languages were considered. We contacted authors for clarification of trial methods and data when required. Individual patient data for calculation of means and standard deviations were not available.

- Data extraction
- Review authors extracted data and trial details using a pre-piloted data extraction form developed for this review. Primary authors of the included trials were contacted to provide information for missing data and trial information. We also sought individual

patient data to enable comparisons of mean values across studies. To perform intention-to-treat analyses, all data extracted reflected the original allocation groups where possible. Losses to follow up were identified where this information was given. Any differences were settled by consensus.

For the majority of trials, we estimated means and standard deviations from graphs presented without tabulated data in the trial reports. During editorial processing of the review, data extraction from graphs was repeated by Helen Handoll, acting in an editorial capacity and not as an author, and a final data set agreed with MB.

- Quality assessment
- Study quality was assessed using an adaptation of the method outlined in Schulz 1995. The results of the quality assessment are presented in a descriptive manner. We assessed adequacy of randomisation, adequacy of allocation concealment, potential for selection bias and the level of masking. Details of the assessment categories are shown in Table 02.

- Analyses
- Analyses were performed using the RevMan 4.2.3 software. We conducted intention-to-treat analyses wherever possible. Relative risks and 95% confidence intervals (CI) were calculated for dichotomous outcomes, and mean differences and 95% confidence intervals calculated for continuous outcomes. Results of comparable groups of trials were pooled using the fixed-effect model. We analysed different injury categories separately (tendon/ligament injury, DOMS). Heterogeneity between comparable trials was estimated using the I2 statistic and consideration given to the appropriateness of pooling. Where there was an indication of significant heterogeneity, we stipulated analysis using a random-effects model.

- Sensitivity analyses
- Where appropriate, we planned to perform sensitivity analyses investigating the effects of study quality based on the Schulz quality score (Schulz 1995) and missing data. For the latter we planned best and worst case analyses. The best-case scenario assumes that none of the originally enrolled participants missing from the primary analysis in the treatment group had the negative outcome of interest whilst all those missing from the control group did. The worst-case scenario is the reverse.

- Subgroups
- Where appropriate data were available, we considered subgroup analysis based on the following.
- (1) Injury entry grade or severity using an established specific injury classification system where the authors have employed such a system.
- (2) Type of injury including anatomical location.
- (3) Dose of oxygen received (pressure, time and length of treatment course).
- (4) Nature of the comparative treatment modalities, including no specific therapy.
- (5) Age (adults versus children).
- (6) Nature of the activity undertaken.

Tests of interaction were calculated to determine if the results for subgroups were significantly different. Statistical heterogeneity was assumed to be significant if the I2 analysis suggested more than 30% of the variability in an analysis was due to differences between trials. Consideration was then given to the appropriateness of pooling and meta-analysis.

Description of studies

We identified 24 publications apparently dealing with the use of HBOT for the treatment of soft tissue injuries including DOMS. Initial examination confirmed four were reviews without new data, four did not involve the application of HBOT, two were case reports or case series, one

was not a clinical study and one was an animal study. These reports were excluded, leaving 13 publications of possible randomised comparative trials. After appraisal of the full reports we included nine trials, two (Staples 1999a; Staples 1999b) of which were reported in the same paper and represent 'phase 1' and 'phase 2' of a two stage study with different comparisons in each phase. Three papers were abstracts (Babul 2000b; Mekjavic 1996; Soolsma 1997) of included trials (Babul 2003; Mekjavic 2000; Soolsma 1996). We excluded one non-randomised comparative trial (Todorovic 1996) (see 'Characteristics of excluded studies' table).

The nine included trials were published between 1996 and 2003, and from a limited number of centres in Canada (Babul 2003; Germain 2003; Soolsma 1996; Staples 1999a; Webster 2002), the USA (Borromeo 1997; Harrison 2001) and Europe (Mekjavic 2000). The reviewers are unaware of any ongoing RCTs in the area. In total, these trials recruited 219 participants but presented results for only 197 participants (90%). The number of participants in each trial ranged from 12 (Webster 2002) to 49 (Staples 1999a). Further details of the trials are presented in the 'Characteristics of included studies' table.

Two trials evaluated HBOT for treating acute soft tissue injury: Borromeo 1997 enrolled individuals with acute ankle sprains presenting within 72 hours to an orthopaedic surgeon, while Soolsma 1996 enrolled individuals with grade II medial collateral ligament injuries in one knee who similarly presented within 72 hours. The other seven trials included young adult unconditioned volunteers who underwent exercise designed to produce DOMS under controlled conditions. Exercise intensity and duration varied across these studies, but all except Webster 2002 involved multiple repetitions of resistance to lengthening of the target muscle group (eccentric exercise). Four trials exercised the quadriceps. Three of these (Babul 2003; Staples 1999a; Staples 1999b) specified the non-dominant leg and used the same protocol; the other used a similar protocol involving up to 150 repetitions (Germain 2003). Two studies exercised the forearm flexors, involving maximal resistance to elbow extension for 60 and 72 repetitions respectively (Harrison 2001; Mekjavic 2000). The remaining study (Webster 2002) involved bilateral calf muscles raises against an 80% of maximal load - five repetitions to failure. None of the trials reported a failure to produce DOMS in any study participant, and all trials indicated the use of these exercise protocols in previous studies.

Both the dose of oxygen per treatment session and for the total course of treatment varied between studies. The lowest dose administered was 2.0 atmosphere absolute (ATA) for 60 minutes on three occasions (intervention groups in Staples 1999a and Staples 1999b), while the highest single treatment dose was 2.5 ATA for 100 minutes for five sessions over three days (Germain 2003; Harrison 2001). The longest course was in Soolsma 1996 who applied 60 minute treatments for 10 days. All authors therefore used between 2.0 ATA and 2.5 ATA as a maximum oxygen pressure and the total number of individual treatment sessions varied from three to 10. The mean time between injury and compression was 33 hours in Borromeo 1997 and 74 hours in Soolsma 1996. Most DOMS trials administered oxygen or sham therapy immediately (up to four hours) after the exercise session, the exceptions being one of the two HBOT groups in both Harrison 2001 and Staples 1999a, who received the first treatment approximately 24 hours after exercise ('delayed treatment').

Active HBOT was compared to a sham hyperbaric oxygen exposure breathing air at a trivial pressure in six trials (Babul 2003; Borromeo 1997; Soolsma 1996; Staples 1999a; Staples 1999b; Webster 2002). The same type of sham exposure was used for the delayed HBOT groups in Harrison 2001 and Staples 1999a, while Mekjavic 2000 employed sham exposure at pressure by administering an 8% oxygen mixture to keep inspired oxygen tension equal to that at one atmosphere. No sham was used in the control groups of Germain 2003 and Harrison 2001, and one of the two control groups of Staples 1999a.

The follow-up period varied between trials, ranging from day three following exercise (Babul 2003) to six weeks (Soolsma 1996). Borromeo 1997 followed participants to full functional recovery. All included studies reported at least one outcome of interest. Of the outcomes identified above, the trials reported data on two primary outcomes (time to full functional recovery and proportion returning to full function) and three secondary outcomes of interest (functional assessments, pain and swelling, and muscle strength).

Other outcomes reported (including non-clinical) include: active and passive range of motion (Borromeo 1997; Soolsma 1996), average power at varying degrees of joint position (Germain 2003), serum creatine kinase (Babul 2003; Germain 2003; Harrison 2001), serum malondialdehyde (Babul 2003), magnetic resonance imagery (Babul 2003; Harrison 2001; Soolsma 1996; Webster 2002), magnetic resonance spectroscopy (Webster 2002), ratio of figure of eight to straight running ability (Soolsma 1996) and transcutaneous oxygen measurement (Harrison 2001; Mekjavic 2000).

Methodological quality

Details of the quality assessment are given in the 'Characteristics of included studies' table. In general, study quality was assessed as fair to high with regard to methodology. The significance of variations in quality detailed below is unclear. Given that few analyses could be pooled, study quality was not used as a basis for sensitivity analysis.

- Randomisation
- Randomisation procedures were described in Babul 2003 (random number table (Babul 2005)) and Borromeo 1997 (random-number table), but not in the other seven studies. Allocation concealment was adequately described only by Babul 2003. For none of the remaining studies is there a clear indication that the investigators were unable to predict the prospective group to which a participant would be allocated.

- Participant baseline characteristics
- Participants entered into Borromeo 1997 had all suffered acute lateral ankle sprains and had received no specific treatment other than ice, elevation, crutches and elastic bandaging, while for Soolsma 1996 participants were enrolled with grade II medial collateral ligament injuries. In both trials, participants had presented to an orthopaedic surgeon within 72 hours (Borromeo 1997: mean 33 hours to compression; Soolsma 1996: mean 74 hours to compression). Participants entered into all other trials were young healthy volunteers who were not conditioned athletes and who had not exercised vigorously for three months prior to entry into the studies (Harrison 2001 did not specify a time period). Babul 2003 enrolled females only; Harrison 2001, Mekjavic 2000, Staples 1999a, Staples 1999b and Webster 2002 enrolled males only; and Borromeo 1997, Germain 2003 and Soolsma 1996 enrolled both males and females. In total, 42 trial participants (19%) were female.

- Blinding
- Seven trials utilised a sham therapy in order to mask participants to HBOT (Babul 2003; Borromeo 1997; Mekjavic 2000; Soolsma 1996; Staples 1999a; Staples 1999b; Webster 2002). One study (Harrison 2001) only provided a sham session for the group receiving delayed HBOT 24 hours after injury, while another (Germain 2003) did not report any blinding of participants or investigators to therapy. No author formally tested the success of their blinding strategy.

- Participants lost to follow up
- Five trials did not report any losses to follow up or any violation of the study protocol (Babul 2003; Borromeo 1997; Mekjavic 2000; Staples 1999b; Webster 2002). One person with an exercise-related complication was excluded before therapy in Germain 2003. Harrison 2001 lost two control participants and one immediate-HBOT group participant; all three participants were excluded from the analyses. Staples 1999a was difficult to interpret in this regard, but ultimately did not report on 13 participants, nine of whom did not complete the study (allocation unknown), and four of whom were rejected due to displaying increased strength after the eccentric exercise protocol (one each lost from control, sham, immediate HBOT and delayed HBOT). Soolsma 1996 enrolled 19 participants, of whom only 14 finished the clinical assessment and only nine completed the MRI investigation. Numbers allocated to each arm in this study were not stated. Sensitivity analysis using best and worse case scenarios have not been performed as there were no dichotomous outcomes involving those studies with losses to follow up.

- Intention-to-treat analysis
- None of the included trials specifically indicated an intention-to-treat approach; however five trials (see above) reported full follow up and did not report any protocol violation.

Results

We first present the results of the two trials assessing HBOT for acute injuries, respectively acute ankle sprains (Borromeo 1997) and acute injury to the medial collateral ligament of the knee (Soolsma 1996). We then present the results of the seven trials that tested HBOT for young adult unconditioned volunteers who underwent exercise designed to produce DOMS.

HBOT for acute ligament injury

- Primary outcomes
- Proportion returning to pre-injury activity
- Only Borromeo 1997 reported this outcome and involved 32 participants with ankle sprains, 16 allocated to HBOT and 16 to sham HBOT. All participants returned to full activity.

- Time to reach full function following injury
- Again, only Borromeo 1997 reported this outcome. There was no statistical significance in the mean time to recovery of full function (see Graph 01.01: mean difference (MD) 0.60 days, 95% confidence interval (CI) -12.91 to 14.11 days).

- Persisting pain following injury
- No trial reported this outcome.

Secondary outcomes

- Functional assessment scores
- Both trials reported functional assessment scores. Based on an unvalidated seven-point scale, where successive scores represented an increasingly difficult level of functional activity, Borromeo 1997 found no significant difference between groups in the functional scores attained at the end of the final treatment session (see Graph 01.02: mean difference (MD) 1.00, 95% CI -0.41 to 2.41). However, Borromeo 1997 noted a significantly greater improvement in scores in the HBOT group compared with those in control group (see Graph 01.02: MD 1.40, 95% CI 0.15 to 2.65; P = 0.03). Graph 01.03 shows the subjective recovery of knee function results (presumed here to be on a 0 to 100 scale where 100 equals full recovery) at three follow-up times for the 14 participants clinically followed up in Soolsma 1996. In presenting the results for this trial, we have assumed that there were seven participants in each group. None of the very small differences between the two groups in functional scores at two, four and six weeks were statistically significant (scores at
- 6 weeks: MD 0.30, 95% CI -2.72 to 3.32).

- Pain and swelling
- Subjective pain scores, reported for both trials, decreased over time in participants of both groups. Pain scores were higher for the HBOT group of Borromeo 1997 at each measurement time. Borromeo 1997 found there was no significant difference between the HBOT and control group in pain scores after the third and final treatment session (see Graph 01.04: MD 5.00, 95% CI -2.07 to 12.07) or in the decrease in pain from the initial scores (data not shown). Again assuming there were seven participants in each group of Soolsma 1996, the mean pain scores were statistically significantly better in the HBOT group after 10 treatments (two weeks), but not after five treatments (one week) or at four weeks follow up (see Graph 01.04: MD -1.20, 95% CI -8.36 to 5.96). The two-week result is no longer statistically significant when eight participants are

assumed in the HBOT group and six in the control group (MD -12.00, 95% -24.31 to 0.31: Graph not shown).

Swelling of the affected joint was measured in different ways in the two trials. Borromeo 1997 reported no significant difference between the two groups in the reduction of the foot and ankle volume, determined by water displacement, after each of the three treatments or overall (26 ml with HBOT versus 32 ml with sham HBOT). Soolsma 1996 found the mean difference in knee girth between the normal and injured sides, assessed by tape measure at four weeks, was less in the HBOT group (0.11 cm versus 0.43 cm). This difference was not statistically significant (see Graph 01.05: MD 0.32 cm shorter with HBOT, 95% CI 0.66 cm shorter to 0.02 cm longer).

- Strength
- Soolsma 1996 found no significant difference between the two groups in the mean difference between the non-injured and injured side in the one-legged jump distance at end of therapy (MD -4.30 cm, 95% CI -17.68 to 9.08 cm), or at four weeks (MD -5.30 cm, 95% CI -12.76 to 2.16 cm): see Graph 01.06.

- Complications of therapy
- Borromeo 1997 reported there was no adverse effects in either treatment group, however the participants in this trial were highly selected and excluded those with an upper respiratory tract infection or a past history of claustrophobia.

HBOT for experimentally induced DOMS

Primary outcomes

- Proportion returning to pre-injury activity
- None of the seven trials in this category reported these outcomes. This reflects the experimental nature of these trials (Babul 2003; Germain 2003; Harrison 2001; Mekjavic 2000; Staples 1999a; Staples 1999b; Webster 2002), none of which tested the effect of HBOT on DOMS arising from sports activity.

- Time to reach full function following injury
- No trial reported this outcome.

- Persisting pain following injury
- No trial reported this outcome.

- Secondary outcomes
- No data were available for pooling from Babul 2003, a small trial of 16 female participants. This trial assessed pain, swelling and strength at multiple times up to 72 hours following exercise, however only the differences between control and HBOT groups were reported rather than outcomes in each group, and we were unable to obtain suitable data for meta-analysis. Only limited data were available from Germain 2003; even where continuous data were available, the numbers in the two treatment groups were not; the treatment group of the participant lost from follow up was also not reported. It should be noted that for most of the outcomes presented here, data were estimated from graphs in the trial reports.

Data from comparisons in two trials (Harrison 2001; Staples 1999a) testing the effect of delayed HBOT are presented separately from those testing immediately applied HBOT in the following.

- Functional assessment scores
- No trial reported data on this outcome

Pain and swelling

- 1. Pain scores (10 = worst pain) with immediate HBOT
- Pooled data from four trials (Harrison 2001; Mekjavic 2000; Staples 1999a; Staples 1999b) for pain scores at 24, 48 and 72 hours, and from between four and seven days are shown in Graph 02.01. These show no significant differences between the two groups at 24 hours or later on (at end of treatment), but statistically significant differences in favour of the control group at 48 hours (MD 0.88, 95% CI 0.09 to 1.67) and 72 hours (MD 0.72, 95% CI 0.06 to 1.37). Heterogeneity was assessed as low for each comparison (I^2 = 0%). Subgroup analysis by muscle group exercised showed a similar effect with regard to arm and leg muscles (see Graph 02.02). Participants were pain free by 15 days in Harrison 2001 and were nearly pain free at 10 days in Mekjavic 2000.

Two trials did not report standard deviations (Babul 2003; Germain 2003) for pain data. Babul 2003 reported there was no difference in perceived muscle soreness between the two groups at 24, 48 or 72 hours after exercise (mean difference in visual analogue scale score (0-10) at 72 hours between control and HBOT: MD 1.35, 95% CI 0.07 to 2.64; this was reported as being no longer statistically significant after applying a Bonferroni correction for multiplicity of outcomes). Though Germain 2003 reported muscle soreness had returned to baseline levels at day three for the HBOT group while still being elevated for the control group, there were apparently no significant differences in the overall results over time. The presentation of the pain results of Webster 2002 was unclear and incomplete and could not be used to confirm the reported enhanced recovery for pain sensation in the HBOT group.

- 2. Pain scores (10 = worst pain) with delayed HBOT
- Pooled data from the two trials (Harrison 2001; Staples 1999a) examining delayed HBOT for pain scores at 24, 48 and 72 hours, and at four and seven days respectively (see Graph 02.03). These show no significant differences between the two groups at 24 or 48 hours or later on (at end of treatment), but statistically significant differences in favour of the control group at 72 hours (MD 0.85, 95% CI 0.06 to 1.64). However, the results for the two trials were significantly heterogeneous for this follow-up time (I^2 = 61.6%).

- 3. Swelling
- Various physical measures were used to represent swelling. Three trials (Babul 2003; Germain 2003; Harrison 2001) reported on limb circumference; and two trials (Harrison 2001; Webster 2002) reported respectively on the actual values and percentage change from baseline for the cross-sectional area of different muscles. Babul 2003 and Germain 2003 did not report mean difference or standard deviations. Babul 2003 reported there was no difference in quadriceps circumference, measured at 10 cm and 20 cm above the patella, between the two groups at 24, 48 or 72 hours after exercise (mean difference in quadriceps circumference (10 cm level) at 72 hours between control and HBOT: MD -0.66 cm, 95% CI -6.52 to 5.19 cm). Germain 2003 reported there were no significant differences between the two groups or across time. Graph 02.04 shows the results at different times for the other three trials testing immediate HBOT; there were no statistically significant differences between the HBOT and control groups for any trial. This was also the case for the results of delayed treatment in Harrison 2001 (see Graph 02.05).

- Strength
- The strength of the various muscles specifically exercised in the seven trials was measured and reported in several ways. Four trials (Babul 2003; Germain 2003; Staples 1999a; Staples 1999b) reported maximal eccentric quadriceps muscle torque in Newton metres (Nm). However, Babul 2003 did not report mean values or standard deviations in either group and therefore did not contribute to the pooled result. Germain 2003 did not report the numbers of participants in each group. Sensitivity analyses allowing for seven participants in the HBOT group and eight in the control group, or vice versa, in Germain 2003 showed non-significant results between the two groups in muscle torque. Harrison 2001 reported the percentage of the initial isometric strength of forearm flexors, while Mekjavic 2000 reported the maximal isometric strength of elbow

flexor muscles in kilopascals. Webster 2002 reported the percentage reduction of peak torque calf muscles.

Graph 02.06 shows the pooled results at different times for five of the seven trials testing immediate HBOT: there were no statistically significant differences in the various measures between the HBOT and control groups for any trial. This was also the case for the results of delayed treatment in Harrison 2001 (see Graph 02.07). The variety of measures used means that the actual pooled results in both these graphs are difficult to interpret. The main message is the lack of statistically significant difference as well as the low heterogeneity ($I^2 = 0\%$) at all times for the two comparisons, with the one exception being the 96 hours results for the delayed HBOT versus control comparison ($I^2 = 64.4\%$). It is also notable that recovery of muscle strength (88% versus 82%) was incomplete in both groups of Harrison 2001 by day 15. In contrast, the results of both groups of Webster 2002 exceeded their initial values (101.5% versus 103.9%) by day five. Babul 2003 reported there was no difference in maximal eccentric torque of the quadriceps muscle between the two groups at 24, 48 or 72 hours after exercise (mean difference in maximal eccentric torque at 72 hours between control and HBOT: MD -28.25 Nm, 95% CI -58.21 to 1.71 Nm).

- Adverse effects of therapy
- No trial reported complications of HBOT. The exclusion of one participant from Germain 2003 due to quadriceps muscle compartment syndrome occurred prior to treatment and is likely to have resulted from the exercise protocol.

Discussion

This review has included data from nine trials and we believe these represent all randomised controlled clinical trials in this area, both published and unpublished, at the time of searching the databases. While we have made every effort to locate further unpublished data, it remains possible that this review is subject to a positive publication bias, with generally favourable trials more likely to achieve reporting. Given this possibility, the general lack of benefit detected for HBOT for the two trials of closed soft tissue injuries (ankle and knee sprains) or the seven trials of experimentally induced DOMS is notable. Another limitation is the lack of data on long term effects or on quality of life outcomes.

We located only nine trials with 219 participants in total, and there were substantially fewer participants in the data available for pooling. Two trials (Germain 2003; Soolsma 1996) failed to provide the numbers of each group included in their results: intention-to-treat analysis was not possible for these. Most of the data presented in the review graphs were estimated from graphs published in the trial reports. While clearly unsatisfactory, this was the best we could do in the absence of information from the trial investigators. The general scarcity of data precluded most subgroup analyses but also it is notable that, with few exceptions, the results of trials testing HBOT for DOMS were homogeneous. Other problems for this review were the failure to report on primary functional outcomes in many studies, poor reporting of means and standard deviations, the variable methods used for reporting similar outcomes across studies and the lack of data regarding the treatment of uncontrolled muscle injury. In particular, the concentration of these studies on a short-term, self-limiting injury with a 100% recovery rate (DOMS) demands a cautious interpretation of the results.

For ankle sprains, Borromeo 1997 reported no significant benefits in the return to previous activities, in time to recovery, in functional outcomes, pain or swelling. Though the authors found a statistically significant improvement for the HBOT group in the change scores for ankle function, the practical significance of this finding should be interpreted cautiously as this scale has not been validated and the clinical impact is difficult to assess.

The trial of HBOT for grade II medial collateral ligament injury conducted by Soolsma 1996 (only reported to date in an unpublished Master of Science thesis) has several features that remain unclear. Importantly, the number of participants allocated to each arm and the scales on which a number of the outcomes are measured are unknown. Our inability to conduct intention-to-treat

analyses for this trial and the difficulties in assessing clinical significance severely restricts the usefulness of this small trial.

We found no evidence that HBOT improves the speed of recovery from delayed onset muscle soreness (DOMS) following eccentric exercise designed to cause this problem. There was some indication from the analysis of pooled data from four trials (Harrison 2001; Mekjavic 2000; Staples 1999a; Staples 1999b) that HBOT might actually hinder recovery from muscle soreness, (e.g. at 48 hours after injury there was a statistically significant difference in pain scores between the groups of 0.88 points on a 0 to 10 scale), while there was no evidence of improvement in swelling or the return of muscle strength. These results were relatively uniform, and subgroup analysis by the site of muscle injury did not suggest a differential effect of HBOT for different muscle groups. The clinical significance of the modest differences in reported pain is unclear. There were no differences between the two groups in any of the physical measures of swelling or muscle strength. Similarly, the response to treatment when HBOT was delayed for 24 hours did not suggest important effects in the relevant groups from Harrison 2001 and Staples 1999a.

None of these reviewed trials reported adverse effects with HBOT or control therapies, so we are unable to assess any negative impact of HBOT on the outcome of these patients other than the outcomes discussed above. HBOT is generally regarded as a relatively benign intervention. There are few major adverse effects (pulmonary barotrauma, drug reactions, injuries or death related to chamber fire). There are a number of more minor complications that may occur commonly. Visual disturbance, usually reduction in visual acuity secondary to conformational changes in the lens, is very commonly reported - perhaps as many as 50% of those having a course of 30 treatments (Khan 2003). While the great majority of patients recover spontaneously over a period of days to weeks, a small proportion of patients continue to require correction to restore sight to pre-treatment levels. The second most common adverse effect associated with HBOT is barotrauma. Barotrauma can affect any air-filled cavity in the body (including the middle ear, lungs and respiratory sinuses) and occurs as a direct result of compression. Aural barotrauma is by far the most common as the middle ear air space is small, largely surrounded by bone and the sensitive tympanic membrane, and usually requires active effort by the patient in order to inflate the middle ear through the eustachian tube on each side. Barotrauma is thus not a consequence of HBOT directly, but rather of the physical conditions required to administer it. Most episodes of barotrauma are mild, easily treated or recover spontaneously and do not require the therapy to be abandoned. Less commonly, HBOT may be associated with acute neurological toxicity manifesting as seizure. While there was no report of adverse effects of HBOT in any of the included trials, a careful selection of participants was evident in most.

Reviewers' conclusions

Implications for practice

There was insufficient evidence from comparisons tested within randomised controlled trials to establish the effects of HBOT on ankle sprain or acute knee ligament injury, or on experimentally induced DOMS. There was some evidence that HBOT may increase pain in DOMS. Thus, the use of HBOT in these patients cannot be justified by this review.

Implications for research

Given the findings of this review, the self-limiting nature of the injury and the availability of other interventions, there is little case for further investigation of HBOT as a possible therapy for DOMS. While more information may be useful on a range of real clinical injuries, subsets of injury severity and time of presentation, any further investigations would need to be carefully justified. The effect of differing oxygen dosage and effect of other therapies administered simultaneously is not known. Any future trials would need to consider in particular:

- appropriate sample sizes with power to detect expected differences;
- careful definition and selection of target patients;
- appropriate range of oxygen doses per treatment session (pressure and time);
- appropriate and carefully defined comparator therapy;
- use of an effective sham therapy;
- effective and explicit blinding of outcome assessors;
- appropriate outcome measures including all those listed in this review;
- careful elucidation of any adverse effects;
- the cost-utility of the therapy;
- appropriate and full reporting.

Acknowledgements

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Potential conflict of interest

Dr Bennett is a hyperbaric physician who does not routinely treat soft-tissue injuries or delayed onset muscle soreness. Several included trials have been conducted by authors of this review (JB, SB, JT, ML). These individuals were not involved in the selection or critical appraisal of their own studies.

Tables

Characteristics of included studies

Study	Babul 2003
Methods	Randomised (random-numbers table), concealed allocation and patient and assessor blind. No report of intention-to-treat analysis or of exclusions.
Participants	16 healthy female volunteers. Underwent deliberately provocative exercise of non-dominant quadriceps muscle.
Interventions	HBOT100% oxygen at 2.0 ATA for 60 minutes at 4, 24, 48 and 72 hours post-injury.CONTROLSham HBOT at 1.2 ATA on air on the same schedule.
Outcomes	PAIN SCOREVisual analogue scale (0 to 10)STRENGTHChange from baseline expressed as maximum eccentric torque in Nm.SWELLINGTape measurement by blinded researcher at a standard point. expressed relative to pre-injury value.
Notes	Schulz rating: Randomisation - AAllocation concealment - ASelection bias - ADouble-blinding - AVery small study with multiple outcomes.Complex experimental design with 2 distinct phases with somewhat different therapy arms.
Allocation	A

concealment	
Study	Borromeo 1997
Methods	Randomised, patient and assessor blind. Intention-to-treat analysis with 100% follow up.
Participants	32 adults (11 females) with lateral ankle sprain within 72 hrs (mean 33 hours). Only rest, ice and elevation prior to enrolment. Excluded if fractured or specific contra-indication to HBOT.
Interventions	BOTH GROUPSPosterior splint, crutches, NSAID, active ROM exercises, ankle stirrup.HBOTHBOT at 2.0 ATA on 100% oxygen for 90 minutes, 3 sessions over 7 days.CONTROLSham HBOT exposure to 1.1 ATA breathing air for 90 minutes, 3 sessions over 7 days.
Outcomes	HEALED AT FINAL FOLLOW UPTIME TO NO FURTHER SYMPTOMSFUNCTIONAL SCORE(1) Time to reach maximum on 7 point scale. Recorded by blinded researcher.(2) Highest level attained on a 7 point functional scale. PAIN SCOREVisual analogue scale (0 to 10).SWELLINGAssessed using a water displacement volumeter.
Notes	Schulz rating: Randomisation - AAllocation concealment - BSelection bias - ADouble-blinding - ARelatively long delay to treatment and small number of compressions.The researcher measuring outcomes underwent a comparison with three sports physicians using 10 other cases of ankle sprain. There were high inter-observer regression coefficients for all physical measures on patient examination.
Allocation concealment	B
Study	Germain 2003
Methods	Randomised, not blinded. Intention-to-treat status unknown with 1 missing participant not accounted for.
Participants	16 healthy volunteers (10 females). Underwent deliberately provocative exercise of quadriceps muscle.
Interventions	HBOT95% oxygen at 2.5 ATA for 100 minutes at 1 and 6 hours post injury, then 1 treatment the next day and 2 treatments on the next day separated by 6 hours.CONTROLNil specific therapy.
Outcomes	PAIN SCOREVisual analogue scale (0 to 100).STRENGTHChange from baseline measured as maximum torque measured in Nm.SWELLINGTape measure at standard point by blinded observer.
Notes	Schulz rating:Randomisation - BAllocation concealment - BSelection bias - CDouble-blinding - CVery small study with multiple outcomes. We do not know how many in each arm or which arm the missing volunteer was lost from.
Allocation concealment	B
Study	Harrison 2001
Methods	Randomised, patient partial blinding. No intention-to-treat analysis but exclusions are accounted for. Complex experimental design with 2 active treatment groups.

Participants	21 healthy male volunteers. Underwent deliberately provocative exercise of elbow flexors.
Interventions	HBOT (2 groups)(1) Immediate HBOT: 100% oxygen at 2.5 ATA for 100 minutes. Treatments immediately post-injury and 24, 48, 72 and 96 hours.(2) Delayed HBOT. Immediate sham (on air at minimal pressure), then the same HBOT schedule as group 1.CONTROLNo specific therapy.
Outcomes	PAIN SCOREVerbally anchored 10 point scale (estimated from graphical representation).STRENGTHChange from baseline as maximum strength measured in kilograms.SWELLINGCross-sectional area estimated from MRI in mm squared.
Notes	Schulz rating:Randomisation - CAllocation concealment - BSelection bias - CDouble-blinding - B Personal communication confirms partial blinding and random allocation. Pain scores were given only with SEM and have been converted to SD.
Allocation concealment	B
Study	Mekjavic 2000
Methods	Randomised, patient and statistician blind. Intention-to-treat analysis with 100% follow up.
Participants	24 healthy male volunteers. Underwent deliberately provocative exercise of elbow flexors.
Interventions	HBOTStandard exercise protocol followed by 7 sessions in 100% oxygen for 60 minutes daily at 2.5 ATA.CONTROLStandard exercise protocol followed by 10 sessions in a sham hyperbaric treatment (2.5 ATA, 8% oxygen for 60 min), once daily.
Outcomes	PAIN SCOREVisual analogue scale (0 to 10) (estimated from graphical representation).STRENGTHChange from baseline as maximal isometric strength in kilopascals before and for 10 days following exercise. Measured by blinded researcher. (Estimated from graphical representation.)SWELLINGArm circumference (cm)
Notes	Schulz rating: Randomisation - BAllocation concealment - BSelection bias - ADouble-blinding - ASmall study with multiple outcomes. Most point estimates are derived from graphs.The number of treatment sessions was 10 in the extended abstract report of this trial. We have taken the number (7) in the peer-reviewed publication.
Allocation concealment	B
Study	Soolsma 1996
Methods	Randomised, method not specified. Participant and assessor blind. No intention-to-treat analysis.
Participants	19 participants (5 females) with grade II injury to the medial collateral ligament of the knee suffered during sporting activity and confirmed by magnetic resonance imaging. All were adults, without history of similar injury or surgery to the knee and who presented to an orthopaedic

	surgeon within 72 hours of injury.14 participants finished the clinical stage and 9 had final MRI.
Interventions	BOTH GROUPSRegular icing, stretching and strengthening exercise rehabilitation program.Within 96 hours of injury participants received either: HBOTAt 2.0 ATA on 100% oxygen for 60 minutes, 10 sessions over 2 weeksCONTROLSham HBOT exposure to 1.2 ATA breathing air on the same schedule.
Outcomes	SUBJECTIVE RECOVERY INDEXparticipants self-completed a questionnaire.PAIN SCOREVisual analogue pain scale (0 to 10) (estimated from graphical representation).RANGE OF MOTIONONE-LEGGED HOP TESTSWELLINGChanges in girth measured with a tape and volume performed by blinded researcher from magnetic resonance imaging: pre- versus post-treatment volumetric analysis with two blinded radiologists reaching consensus. FIGURE OF EIGHT PERFORMANCE TESTTime taken to complete a standard course, measured by a blinded researcher.
Notes	Schulz rating:Randomisation - BAllocation concealment - BSelection bias - CDouble-blinding - ARelatively long delay to treatment .
Allocation concealment	B
Study	Staples 1999a
Methods	Randomised, participant and probably assessor blind. No intention-to-treat analysis but exclusions were reported (see next section).
Participants	49 healthy male volunteers. Underwent deliberately provocative exercise of non-dominant quadriceps muscle. Nine individuals were randomised but did not complete the study (recent respiratory track infection or confinement anxiety). There was no indication to which group these participants were allocated. Four participants, one from each group, excluded because of abnormal response to exercises: increased muscle torque,
Interventions	Phase 1 (see Notes)HBOT (2 groups)(1) 100% oxygen at 2.0 ATA for 1 hour at 0, 24 and 48 hours after exercise, followed by two sham treatments at 72 and 96 hours.(2) Sham at 0 and 24 hours, followed by HBOT at 48, 72 and 96 hours.CONTROL (2 groups)(1) No specific intervention.(2) Sham HBOT by exposure to 1.2 ATA breathing air at 0, 24, 48, 72 and 96 hours for one hour on each occasion.
Outcomes	PAIN SCOREVisual analogue (0 to 10) (estimated from graphical representation).STRENGTHChange from baseline as maximal eccentric torque measured in Nm (estimated from graphical representation).
Notes	Schulz rating:Randomisation - BAllocation concealment - BSelection bias - CDouble-blinding - AComplex protocol makes interpretation difficult. Most point estimates are derived from graphs with means and SEM. Where results have been given with standard errors, these have been converted to standard deviations.Complex experimental design with 2 distinct phases: see Staples 1999b for phase 2.
Allocation	B

concealment	
Study	Staples 1999b
Methods	Randomised, participant and probably assessor blind. Intention-to-treat analysis and no exclusions.
Participants	30 healthy male volunteers. Underwent deliberately provocative exercise of non-dominant quadriceps muscle.
Interventions	Phase 2 (see Notes)HBOT (2 groups)(1) 100% oxygen at 2.0 ATA for 1 hour at 0, 24 and 48 hours after exercise, followed by two sham treatments at 72 and 96 hours.(2) same HBOT on five occasions at 0, 24, 48, 72 and 96 hours.CONTROLSham HBOT by exposure to 1.2 ATA breathing air at 0, 24, 48, 72 and 96 hours for one hour on each occasion.
Outcomes	PAIN SCOREVisual analogue (0 to 10) (estimated from graphical representation).STRENGTHChange from baseline as maximal eccentric torque measured in Nm (estimated from graphical representation).
Notes	Schulz rating: Randomisation - BAllocation concealment - BSelection bias - CDouble-blinding - AComplex protocol makes interpretation difficult. Most point estimates are derived from graphs with means and SEM. Where results have been given with standard errors, these have been converted to standard deviations.Complex experimental design with 2 distinct phases: see Staples 1999a for phase 1.
Allocation concealment	B
Study	Webster 2002
Methods	Randomised, patient and assessor blind. Intention-to-treat analysis with 100% follow up.
Participants	12 healthy young male volunteers. Underwent deliberately provocative exercise of gastrocnemius muscle.
Interventions	HBOT100% oxygen at 2.5 ATA for 60 minutes at 3, 24 and 48 hours post-injury.CONTROLSham HBOT at 1.3 ATA on air on the same schedule.
Outcomes	PAIN SCOREDescriptor differential scale expressed as percentage changes compared to maximal pain. (Data not used due to difficulties in interpretation.) STRENGTHChange from baseline as maximal eccentric torque expressed as percentage (estimated from graphical representation).SWELLINGPer cent change in cross-sectional area of medial gastrocnemius (estimated from graphical representation).
Notes	Schulz rating:Randomisation - BAllocation concealment - BSelection bias - ADouble-blinding - AVery small study with multiple outcomes. Most point estimates are derived from graphs: those for pain were not used - see preceding section.
Allocation concealment	B

ATA: atmospheres absolute
HBOT: hyperbaric oxygen therapy
MRI: magnetic resonance imaging

Nm: Newton metres
NSAID: non-steroidal anti-inflammatory drug
ROM: range of movement
SEM: standard error of the mean
SD: standard deviation

Characteristics of excluded studies

Study	Reason for exclusion
Todorovic 1996	Poorly reported trial with mention of control group, but no indication of allocation method. Heterogeneous injuries and no standard number of HBO exposures. Author contact attempted but not successful.

HBO: hyperbaric oxygen

Additional tables

Table 01 MEDLINE search strategy

MEDLINE (OVID WEB)
1. Athletic Injuries/ 2. Soft Tissue Injuries/ 3. (arm$ or leg$ or muscle$ or tendon$ or ligament$).tw. 4. (injur$ or trauma$ or lesion$ or damage$ or wound$ or destruction$ or oedema$ or edema$ or contusion$ or concus$ or commotion$ or pressur$ or soreness).tw. 5. and/3-4 6. or/1-2,5 7. Hyperbaric Oxygenation/ 8. (high$ adj3 (pressure or tension$)).tw. 9. hyperbaric$.tw. 10. or/8-9 11. oxygen$.tw. 12. and/10-11 13. (HBO or HBOT).tw. 14. ((monoplace or multiplace) adj chamber$).tw. 15. or/7,12-14 16. and/6,15
17. randomized controlled trial.pt. 18. controlled clinical trial.pt. 19. Randomized Controlled Trials/ 20. Random Allocation/ 21. Double-Blind Method/ 22. Single-Blind Method/ 23. or/17-22 24. Animal/ not Human/ 25. 23 not 24 26. clinical trial.pt. 27. exp Clinical Trials/ 28. (clinic$ adj25 trial$).tw. 29. ((singl$ or doubl$ or trebl$ or tripl$) adj (mask$ or blind$)).tw. 30. Placebos/

31. placebo$.tw.
32. random$.tw.
33. Research Design/
34. (latin adj square).tw.
35. or/26-34
36. 35 not 24
37. 36 not 25
38. Comparative Study/
39. exp Evaluation Studies/
40. Follow-Up Studies/
41. Prospective Studies/
42. (control$ or prospectiv$ or volunteer$).tw.
43. Cross-Over Studies/
44. or/38-43
45. 44 not 24
46. 45 not (25 or 37)
47. or/25,37,46
48. and/16,47

Table 02 Quality assessment system for included studies

Randomisation	Alloc. concealment	Selection bias	Masking
A - Adequate sequence generation recorded using random number tables, computer random number generation, coin toss or shuffling	A - Adequate method of allocation concealment such as central randomisation, serial numbered opaque envelopes, or other method where allocation is convincingly concealed	A - Trials where intention to treat analysis is possible and losses to follow up are few	A - Double or triple blind
B - Did not specify one of the methods above, but mentions randomisation method	B - Unclear allocation concealment or no mention of any attempt to conceal allocation listed in A	B - Trials which report exclusions at <10%	B - Single blind
C - Other method of allocation that appears unbiased	C - Inadequate allocation concealment such as medical record number or alteration methods	C - No mention of exclusions, exclusions over 10%, or widely differing between arms of the trial	C - No blinding

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* *indicates the major publication for the study*

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Graphs

Graphs and Tables

To view a graph or table, click on the outcome title of the summary table below.

01 Acute ligament injury: HBOT versus sham HBOT				
Outcome title	No. of studies	No. of participants	Statistical method	Effect size
01 Time to return to prior function (days)			Weighted Mean Difference (Fixed) 95% CI	Totals not selected
02 Ankle function score (0 to 7: full function)			Weighted Mean Difference (Fixed) 95% CI	Totals not selected
03 Subjective recovery scores after knee injury (0 to 100: full recovery)			Weighted Mean Difference (Fixed) 95% CI	Totals not selected
04 Pain scores (0 to 100: worst pain)			Weighted Mean Difference (Fixed)	Totals not selected

			95% CI	
05 Change in knee girth at 4 weeks post medial collateral ligament injury (cm)			Weighted Mean Difference (Fixed) 95% CI	Totals not selected
06 One legged jump distance (difference between non-injured and injured side) (cm)			Weighted Mean Difference (Fixed) 95% CI	Totals not selected

02 Induced DOMS: HBOT versus control

Outcome title	No. of studies	No. of participants	Statistical method	Effect size
01 Pain score (10 = worst pain) after exercise (immediate treatment)			Weighted Mean Difference (Fixed) 95% CI	Subtotals only
02 Pain score (10 = worst pain) after exercise (immediate treatment) by muscle group at 48 hours	4	92	Weighted Mean Difference (Fixed) 95% CI	0.88 [0.09, 1.67]
03 Pain score (10 = worst pain) after exercise (delayed treatment)			Weighted Mean Difference (Fixed) 95% CI	Subtotals only
04 'Swelling' (immediate treatment)			Weighted Mean Difference (Fixed) 95% CI	Totals not selected
05 'Swelling' (delayed treatment)			Weighted Mean Difference (Fixed) 95% CI	Totals not selected
06 Muscle strength (immediate treatment): outcome measures defined in text			Standardised Mean Difference (Fixed) 95% CI	Subtotals only
07 Muscle strength (delayed treatment): outcome measures defined in text			Standardised Mean Difference (Fixed) 95% CI	Subtotals only

Cover sheet

Hyperbaric oxygen therapy for delayed onset muscle soreness and closed soft tissue injury

Reviewer(s)	Bennett M, Best TM, Babul S, Taunton J, Lepawsky M
Contribution of Reviewer(s)	Bennett: Original conception and principal author. Handsearching and study identification, critical appraisal and data extraction. Compilation and completion of the first draft and subsequent versions of the review. Content expert in

	hyperbaric medicine and clinical epidemiology. Babul: Coauthor background and editorial input to discussion. Content expert in sports medical research. Best: Coauthor background, results and discussion, and content expert in sports medicine. Lepawsky: Critical appraisal and data extraction. Content expert in hyperbaric medicine. Taunton: Coauthor background, critical appraisal and data extraction. Content expert in sports medicine. Helen Handoll (editor of Cochrane Bone, Joint and Muscle Trauma Group): Data extraction and restructuring of the results section during editorial review. [Significant contribution without authorship.]
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Date new studies sought but none found	Information not supplied by reviewer
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Date new studies found and included/excluded	30 July 2004
Date reviewers' conclusions section amended	Information not supplied by reviewer
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- Faculty of Medicine, University of New South Wales AUSTRALIA

Synopsis

There is not enough evidence to show that hyperbaric oxygen helps recovery from ankle or knee sprains or from muscle pain and fatigue following unaccustomed exercise

Soft tissue injuries are very common. Hyperbaric oxygen therapy (HBOT) involves people breathing pure oxygen in a specially designed chamber. It is sometimes used to increase the supply of oxygen to the injured area in an attempt to speed recovery. In our review, we found insufficient evidence to determine if HBOT helped people with ankle or knee sprains. We found no evidence that HBOT helped people with muscle injury following unaccustomed exercise, but some evidence that people given HBOT had slightly more pain. Further research on HBOT is not a high priority given the variety of other treatment interventions available.