

## **The effect of hyperbaric oxygen and blood platelet injection therapy on the healing of hamstring injuries in rugby players: A Case series report**

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### **Abstract**

There are a number of ultra-structural and immuno-histochemical studies involving hyperbaric oxygen treatment in skeletal muscle, as well as soft tissue healing. Hyperbaric oxygen therapy, in conjunction with blood platelet injection therapy, serves as a valuable addition to previously known and trusted rehabilitation techniques and protocols for the healing of musculoskeletal or soft tissue injuries. The primary aim of this case report is to describe the effect on the recovery time of hamstring injuries when combining hyperbaric oxygen therapy (HBOT) and platelet rich plasma (PRP) injection therapy with exercise rehabilitation. A retrospective, post-intervention data analysis was used in this case series report. Data, obtained through collaboration with a professional rugby union and an accredited Hyperbaric Medicine (HBOT) Centre, were analysed using the Statistical Programme for the Social Sciences (SPSS) software. The significance value was set at 5%. A significant decrease in the injury time of the hamstring injuries in rugby players was noted, with a 38% reduction in injury time in players with a grade-one injury, and 45.7% reduction in players with a grade-two injury. In terms of recurrent injuries, 62% of players with grade-one injuries remained uninjured after treatment, and the percentage of re-injured players with grade-two injuries was 0% after HBOT, PRP and physical therapy treatment. The notion that the healing time of hamstring injuries will decrease when HBOT and PRP are administered in conjunction with traditional rehabilitation therapy is indicated by the data of this report.

**Keywords:** Hamstring injuries, hyperbaric oxygen, blood platelet, recovery time.

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### **Introduction**

The increasing incidence of injury within professional rugby teams has prompted the need for more effective treatments and faster recovery rates (Garraway, Lee, Hutton, Russell & MacLeod, 2000). Muscle injuries pose a difficult problem in traumatology and are the most commonly occurring injuries in sports medicine.

Muscle injuries can be classified into three grades: Grade one, a small number of muscle fibres are stretched or torn, with some localised tenderness or pain. The patient would retain a full range of motion and show no loss of muscle strength; Grade two, a significant number of muscle fibres are torn. Active contraction of the muscle would cause pain. Localised swelling and a palpable depression would present in the muscle belly, and the patient would have a limited range of motion and muscle strength on contraction due to pain; Grade three, a complete rupture of the muscle fibres, resulting in significant or total loss of muscle movement. Extreme pain would initially be felt but would subside quickly due to the separation of the nerve fibres (Brukner & Khan, 2001; Williams, 2004).

Muscles preserve their ability to repair after injury. This healing process has been established to take time. This often leads to a premature return to physical activity, resulting in an increased risk of re-injury due to incomplete muscle recuperation (Kasemkijwattana et al., 1998). Skeletal muscle is able to repair itself through regeneration. An injured muscle, however, often does not completely recover its strength because total regeneration is mired by an increase in fibrosis resulting in fibrotic tissue formation, commonly referred to as scar tissue (Sato et al., 2003). Tissue restoration involves regeneration and fibrosis. Fibroblasts enter the site via the blood circulating in the area.

The scar formed at the injury site consists primarily of collagen fibres and contains very few other cells or blood capillaries, resulting in decreased oxygenation of the area. While this injury site is strong due to the collagen, it lacks the flexibility and elasticity of normal muscle tissues and it is incapable of performing the typical functions of the tissue it has replaced (Marieb, 2005). Biological approaches to improve muscle healing by enhancing muscle regeneration and reducing the formation of fibrosis have been explored. It has been previously determined that insulin-like growth factor-1 (IGF-1), a component of whole blood, suspected to be in high concentrations in PRP (Sampson et al., 2011), can improve muscle regeneration (Kasemkijwattana et al., 1998). Investigators have also used the anti-fibrotic agent decorin to decrease muscle fibrosis subsequent to injury.

Among various healing therapies, as well as different catalysts for the healing of diverse wounds or injuries, hyperbaric oxygen therapy (HBOT), the inhalation of 100% oxygen at greater than atmospheric pressure, may well provide an alternative modality towards reducing the recuperation time of certain musculo-skeletal injuries (Hunt, 1988). The theory behind HBOT is that it accelerates wound healing by increasing oxygen gradients along the periphery of ischemic wounds, as well as sustaining oxygen-dependent collagen matrix growth necessary for angiogenesis (Hunt, 1988). Hyperoxia in normal tissues due to HBOT leads to rapid and significant vasoconstriction, but this is compensated

for by increased plasma oxygen transportation (Babul, Rhodes, Taunton & Lepawsky, 2003).

The micro-vascular blood flow in ischemic tissue is also effectively improved with HBOT (Knighton, Silver & Hunt, 1984). Furthermore, the vasoconstriction effect results in a reduction of post-traumatic tissue edema, which ultimately aids in the treatment of crush injuries, compartment syndromes and burns (Knighton et al., 1984). Previous studies conducted by Mekjavic, Exner, Tesch and Eiken (2000), and Staples, Clement, Taunton and McKenzie (1999) have concluded that HBOT alone has not been shown to have a favourable outcome in the treatment of ankle sprains and delayed onset of muscle soreness (DOMS).

Platelet rich plasma (PRP) or platelet enhanced plasma (PEP) is a portion of blood which is reported to contain large concentrations of growth factors (including vascular endothelial growth factor (VEGF) and insulin-like growth factor [IGF-1]) (Sampson et al., 2011). The blood is obtained from the individual to whom it will be administered. There is emerging evidence on PRP's safety and efficacy in treating muscle injuries due to it enhancing the healing capabilities of musculo-skeletal tissue, primarily by reparative cell signaling (Mishra et al., 2011).

Growth factors, which are soluble proteins able to bind to receptors on the surface of the cell, activate cellular proliferation or differentiation. Typically, after acute wounding, growth factors that show an angiogenic response are released into the wounded area. Under normobaric conditions, the production of VEGF is stimulated by the presence of hypoxia, lactate, nicotinamide adenine dinucleotide and nitric oxide (NO). Hyperoxia, due to HBOT, further stimulates the production and activation of VEGF, present in high concentrations in PRP (Mishra et al., 2011). This stimulates more rapid development of capillary budding, arborisation and granulation tissue formation within the wound bed. An increase in VEGF at the wound base increases vascular protection, inhibition of vascular smooth muscle proliferation, suppression of thrombosis and anti-inflammatory effects, and enhances endothelial cell survival through an increase in NO and prostacyclin. Platelet-derived growth factors (PDGF) produced by fibroblasts, macrophages and keratinocytes stimulate fibroblasts to secrete extracellular matrix (exogenous growth factor), inducing granulation tissue formation, but only when NO production deficiency is corrected. The effect of growth factors present in PRP, which stimulate the healing process of musculo-skeletal tissue, is enhanced through hyperoxia caused by the inclusion of HBOT (Bakker & Cramer, 2002; Mishra et al, 2011).

A previous study was carried out by Sato et al. (2003), combining therapeutic modalities in an effort to create a new biological approach to support healing and recovery of strength after muscle injuries. The findings indicated further

improvement in the healing of muscle lacerations was achieved histologically by the combined administration of IGF-1, a component of PRP, and decorin to improve muscle restoration and decrease the development of fibrosis.

The current study attempted to explore the combined effect of HBOT and PRP injection therapy, with traditional exercise rehabilitation treatment, on the recovery time in hamstring injuries sustained by professional rugby players. The primary aim of the study was to report whether the addition of the HBOT and PRP into a traditional rehabilitation programme for hamstring injuries would affect the return-to-play time of the players.

### **Methodology**

This case series reviews data of professional rugby players from Gauteng province who had their hamstring injuries treated with HBOT, PRP and physical rehabilitation. Ethical clearance was obtained from the University of Johannesburg's higher ethics committee (HEC) and the medical staff of the rugby union and data on these injuries were collected over three years. A total of 42 hamstring injuries were identified and classified either grade 1 (n = 37) or grade 2 (n = 5). The players who participated in the study had a mean age of  $27.87 \pm 3.86$  years.

The gold standard for return to play, as established through experience and analysis of preceding seasons data, and used by the medical staff at the Union, was three weeks (21 days) for a Grade one, and six weeks (42 days) for a Grade two hamstring injury (Brukner & Khan, 2001).

Injuries were diagnosed by a medical doctor, confirmed either on MRI or ultrasound by a radiologist. PRP was then injected as a bolus injection directly into the site of the injury under ultrasound guidance. PRP injections were repeated at seven day intervals until the patient attained pain free full range of motion. No physical therapy was performed in the 48 hours following a PRP injection. The patients underwent HBOT for one hour per day for three consecutive days commencing immediately after the PRP injection each week to a maximum of 11 HBOT sessions in total.

The PRP was prepared using a modified Autologous Conditioned Plasma (ACP) method as follows: 20ml of whole blood was drawn from the patient and sodium citrate added as an anticoagulant. The blood was placed in a Rotafix 32A centrifuge (rotor arm 70mm, max RCF 4226), and centrifuged at 1500 RPM for five minutes. The 2ml of plasma closest to the buffy coat was then withdrawn by means of a pipette to be used as the PRP sample. The remainder of the blood and plasma was discarded.

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The HBOT treatment was carried out at a Hyperbaric Medicine Centre under the supervision of a medical doctor and trained professional staff. The players received a one-hour treatment in the HBOT chambers. This treatment, although a recognised protocol (Wilkinson, 1999), differs from the standard 100-minute treatment protocol, not only in time span, but in that the 100-minute protocol includes two five-minute “air breaks”, the patient being required to breathe normal air (20.9% oxygen, 78% nitrogen, 0.9% argon, 0.1% carbon dioxide) at the treatment pressure for five minutes at both the 30-minute and the 65-minute marks. This is a precautionary measure to reduce the risk of a patient having a hyperoxic fit in the chamber.

The one-hour protocol consisted of the players breathing 100% oxygen while being subjected to a pressure of 2.4 ATA, the pressure equivalent of 14 meters below sea level, for 60 minutes. The players did not receive an air break.

Specialised and player-specific (individualised) treatment protocols for hamstring injuries were carried out by the team’s physiotherapists and biokineticists. The basics for these accelerated treatment protocols are presented in Table 1. During the rehabilitation, the player progressed to the following phase of rehabilitation when they could comfortably complete the current phase with discomfort of less than 2/10 on a VAS. They were regressed back to the previous phase if their level of pain increased above 2/10 after progressing.

**Table 1:** Protocols for the accelerated treatment of hamstring injuries

Phase 1	Phase 2	Phase 3	Phase 4
NSAID	Closed kinetic chain body weight exercises	Increase in resistance training exercises	Asymptomatic
RICE protocol	Multi-angle isometric exercises	Plyometric training	Full-pace agility and speed drills
Isometric muscle exercises	Gluteus Lengthened hamstring exercises	Agility drills	Address bilateral discrepancies
Cycling	Eccentric and concentric isometric exercises	Sub-maximal (80%) running	Initiate return-to-play protocol
Isometric bridging	Alter-Gravity running		

Players were only declared fully recovered and fit to return to full play when they had passed a fitness test consisting of the following:

- Isokinetic testing of concentric and eccentric strength at least equal to pre-injury (baseline) level, equal to the unaffected leg, appropriate to body weight, and with an adequate hamstring:quadriceps ratio

- Straight line sprints of 10m, 40m and 100m completed at baseline times
- Agility testing with timed Illinois and T-drill tests at baseline speeds
- Sports specific drills performed at full speed without any guarding or discomfort

### *Statistical analysis*

Descriptive statistics and frequencies were used to analyse data regarding the number of days each injury took to heal, according to the treatment schedules. Variance was determined using the standard deviation and means. Non-parametric one-sample Wilcoxon Signed-rank Tests were used to determine whether the median of the sample's healing times is equal to a specified standard time of healing. Kendall's Tau-b Test was used to determine the relationship between the acceleration of recovery and the rate of re-injury of the athletes. Group statistics were correlated to determine whether age was an influencing factor in the acceleration of injury recovery. The significance value was set at  $p \leq 0.05$ . Data were analysed using the Statistical Programme for the Social Sciences (SPSS version 20.0).

### **Results**

In three years, 37 Grade-one hamstring injuries were treated using HBOT and PRP, as well as the traditional rehabilitation methods. Grade-one hamstring injuries displayed in Table 2 (N = 37) demonstrated a mean of  $13.1 \pm 6.4$  days injured. It was calculated that the treatment with HBOT and PRP achieved a 38% acceleration in the healing time of these hamstring injuries. This stands in sharp contrast to the norm of 21 days (Brukner & Khan, 2001) for traditional therapies and further research is suggested to determine whether the inclusion of HBOT and PRP could reduce the number of days injured for these participants significantly in relation to the norm.

**Table 2:** Grade-one injuries treated with HBOT and PRP

	<b>Number of injuries</b>	<b>Mean days injured</b>	<b>Standard deviation</b>	<b>Days expected from traditional therapies</b>
Injuries	37	13.1	6.4	21

Table 3 shows re-injury rates of players with the HBOT and PRP protocol that incurred Grade- one injuries. The re-injury rate was 38%. There was no clear correlation between the re-injury rate and the accelerated healing within the study.

**Table 3:** Initial grade 1 injury – Re-injury rates

<b>Occurrence</b>	<b>Number</b>	<b>Percent</b>
Not re-injured	13	62%
Re-injured	8	38%
<b>Total</b>	<b>21</b>	<b>100%</b>

In three years, five Grade-two hamstring injuries were treated using HBOT and PRP, and the accelerated rehabilitation methods (refer to Table 4).

**Table 4:** Grade-two hamstring injuries treated with HBOT and PRP

	<b>Number of injuries</b>	<b>Mean days injured</b>	<b>Standard deviation</b>	<b>Days expected from traditional therapies</b>
Injuries	5	22.8	8.7	42

Grade-two hamstring injuries (N = 5) demonstrated a mean number of days injured of  $22.8 \pm 8.7$  days (54% of the 42 days expected from the standard). It was calculated that the Union achieved a 46% acceleration in the healing time of Grade-two injuries with the inclusion of HBOT and PRP. This also stand in sharp contrast when compared to the norm of 42 days (Brukner & Khan, 2001) for traditional therapies and further research is also suggested to determine whether HBOT and PRP could reduce the number of days injured for these participants significantly in relation to the norm.

**Table 5:** Initial Grade-two injury – re-injury rates

<b>Occurrence</b>	<b>Number</b>	<b>Percent</b>
Not re-injured	3	100%
Re-injured	0	0%
Total	3	100%

A re-injury rate of 0% was seen in Grade-two hamstring injuries treated with the HBOT and PRP protocol (refer to Table 5). Again, no clear correlation between the re-injury rate and the accelerated healing within this study was seen.

A Kendall’s Tau-b correlation was performed to determine the relationship between the acceleration of injury recovery and the incidence of re-injury. The significance ( $P = .292$  and  $P = .132$  respectively) demonstrates that for the purposes of this research there was no correlation between accelerating recovery

and the incidence of re-injury, in either Grade-one or Grade-two hamstring injuries, in professional rugby players.

**Table 6:** Group differences according to age and days saved during injury.

Variable	Age Categories	Frequency (n)	Mean±SD	Significance
Days Saved	Young	25	9.28±8.57	.680
	Old	17	9.17±6.11	

The split-half method applying the mean age of the players ( $M=27.87 \pm 3.86$ ) to determine categorisation of older ( $n = 17$ ) and younger ( $n = 25$ ) players, with 28 years being the dividing age, was used. An Independent Samples Mann-Whitney U Test revealed no significant differences in the number of days saved for younger ( $Md = 13, n = 14$ ) and older participants ( $Md = 11.8, n = 10$ ),  $U = 63, z = -.412, p = .680$ .

### Discussion

The discussion focuses on Grade-one and Grade-two hamstring injuries and their healing time compared with standards set by various researchers and the rugby union. Traditional rehabilitation time for Grade-one hamstring injuries was determined to be 21 days, whereas Grade-two hamstring injuries repair within 42 days (Brukner & Khan, 2001).

In this study, it was observed that the average healing time for Grade-one hamstring injuries treated with HBOT, PRP and physical therapy was 13 days. There was a decrease of eight days (38%) in healing time compared with the traditional healing times used in many practices (Brukner & Khan, 2001). The re-injury rate of the players with Grade-one hamstring injuries who had undergone HBOT, PRP and physical therapy was 38% after treatment.

The average healing time for Grade-two injuries treated with HBOT, PRP and physical therapy was calculated to be 22.8 days. In the case of Grade-two injuries, there was a decrease of 19.2 days (46%) in healing time. The re-injury rate of these players who had undergone HBOT, PRP and physical therapy was 0%. The sample size for Grade-two injuries was small, and it would be suggested that further research be conducted in this area. Further research is suggested to determine whether the observed decrease in the number of days for both Grade-one and Grade-two hamstring injuries is significant when compared to traditional therapies.

In comparison, a study conducted by Warren, Gabbe, Schneider-Kolsky and Bennell (2010), illustrated that the time taken to return to competition ranged



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from one to eight weeks, with a median of 26 days, utilising traditional strength rehabilitation only. It has been noted that this common injury has a high incidence of recurrence, making it one of the most frustrating injuries for players, coaches and their medical staff. Orchard, Marsden and Lord (1997) conducted a prospective study that has shown a recurrence rate of 31% in Australian Football League players who underwent traditional strength and rehabilitation therapy.

It was determined that while the recovery time from injuries was accelerated in these athletes, age, which was previously assumed to have been a factor in recovery, played no significant role in the acceleration of the recovery period. The combination of HBOT, PRP and traditional therapies can therefore be fully credited with the accelerated recovery times seen. The percentage contribution of each method used in this study cannot be significantly apportioned.

Determining the exact concentration of platelets within the PRP is a difficult process requiring the use of specialised equipment. This can be seen as a limitation to not only this study but many of the studies referenced and should be considered a variable in future studies.

#### **Observations**

The case series report observed that the inclusion of HBOT and PRP into exercise rehabilitation protocols did play a role in reducing the amount of time the player spent injured. The risk of re-injury, when accelerating recovery, is usually higher (King, Hume, Milburn & Guttenbeil, 2010). This however, was found not to be the case in this study as the re-injury rate of the players had no significant correlation to the accelerated recovery rate.

This case series report observed that while traditional rehabilitation therapies and procedures have always been appropriate and accepted protocols in the treatment of hamstring injuries in professional rugby players, the inclusion of HBOT and PRP seems to play a role the acceleration of recovery time. For the purpose of elite/professional sport, every day an athlete is injured, not performing or “off the field”, money is potentially lost by the franchise or club to which that athlete belongs. A reduction in the amount of time spent rehabilitating athletes would therefore lead to a reduction in the amount of time an athlete is not earning for the franchise or club.

A substantial decrease in the injury time of the hamstring injuries of rugby players was observed, with a 38% reduction in injury recovery time in players who had suffered a Grade-one injury, and a 46% reduction in players with a Grade-two injury. Other research, by King et al, (2010), declared a 31% injury recurrence rate in Australian Football League players. For the purposes of this study, 38% of players with Grade-one injuries re-injured their hamstring after

treatment, and the percentage of players with initial Grade-two injuries who re-injured their hamstring was 0% after receiving HBOT, PRP and physical therapy treatment. The acceleration of healing time within this study was, found to be insignificantly correlated to the re-injury of the players.

## Conclusion

This study supports the plausibility that the healing time of hamstring injuries may decrease when HBOT and PRP are administered in conjunction with exercise rehabilitation therapies. It is recommended that further research should be done to indicate long term significance of the observations made in this study.

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