activity.

A small percentage of patients will require surgical treatment. Indications for surgery vary but if the patient has had symptoms for over one year or has failed conservative treatment and has sufficient discomfort to cause incapacity then he is usually considered a candidate. While some surgeons advocate radical resection of the synovium or complete exploration of the elbow joint, a more conservative approach includes excision of the tear which is identifiable in the majority of cases or resection of the area of obvious degeneration. One group performed all surgery under local anaesthesia so the site of tenderness could be better localized. Surgery is highly successful for relief of symptoms. Patients usually resume normal activity within a year of operation.

Since injury to the common extensor tendon of the forearm is a cumulative phenomenon, it is important to identify all factors contributing to the development of the condition. The medical literature has not previously noted that the carrying of compressed air tanks associated with scuba diving activities may predispose patients to the development of both acute and chronic lateral epicondylitis. This is not surprising when one considers that the mechanism of injury (a weight load on the forearm with wrist pronation and dorsiflexion) is the exact mechanism required for tank handling.

Conclusion

Although a number of factors have been previously implicated in the formation of lateral epicondylitis, the carrying of compressed air tanks has not been associated with this entity. The authors report five cases of lateral epicondylitis where periods of intensive tank carrying either caused or contributed to the disease. Both research and recreational divers are at risk for the development of the condition.

References

1 Coues WP. Epicondylitis (Franke) or Tennis-Elbow. *Boston Med Surg J* 1914; 170: 461-465.
2 Cyriax JH. The Pathology and Treatment of Tennis Elbow. *J Bone and Joint Surg* 1936; 18: 921-940.
3 Coonrad RW and Hooper WR. Tennis elbow: Its course, natural history, conservation and surgical management. *J Bone Joint Surg* 1973; 55A: 1177.
4 Garden RS. Tennis Elbow. *J Bone and Joint Surg* 1961; 43-B: 100-106.
5 Nirschl RP. Tennis Elbow. Symposium on Sports Injuries. *Orthop Clin North Am* 1973; 4: 787-800.
6 Thorson EP and Szabo RM. Tendonitis of the wrist and elbow. *Occup Med State of the Art Reviews.* 1989; 4: 419-431.
7 Goldie I. Epicondylitis Lateralis Humeri (Epicondylagia or Tennis Elbow): a pathogenetical study. *Acta Chir. Scandinavica. Supplementum* 1964; 339

Dr. Lori L. Barr is an Assistant Professor of Radiology and Pediatrics, University of Cincinnati, Children's Hospital Medical Centre, Cincinnati, Ohio 45229-2899, U.S.A.

Mr. L. R. Martin is the Dive Safety Officer, LGL Ecological Research Associates, Inc., 1410 Cavitt St., Bryan, Texas 77801.

TANK CARRIER'S LATERAL EPICONDYLITIS: A BIOMECHANICAL RATIONALE FOR INJURY AND PREVENTION

Lori L. Barr, Denis Brunt and Larry R. Martin

Introduction

Five cases of lateral epicondylitis, in which the carrying and lifting of compressed air tanks led to injury of the common tendon affixing the extensor muscles of the forearm to the lateral epicondyle, have been reported.[1] The following experiment was performed to investigate the biomechanical effects of tank lifting on the forearm and to determine whether hand position could be altered to reduce the amount of muscle activity during lifting.

Materials and Methods

Four subjects ranging in ages from twenty-eight to forty-five years were asked to lift an A180 compressed air tank filled to capacity (3,000 PSI). Three of the subjects were healthy volunteers with no arm symptoms (subjects 1 - 3). One subject was symptomatic for chronic lateral epicondylitis and will be referred to as Subject S. Subject 1 was 152.5 cm in height, subject 2 167.5 cm, subject 3 170 cm and subject S 167.5 cm.

Surface electrodes were applied unilaterally to the skin overlying the common extensor muscle group of the forearm and the ipsilateral biceps brachii muscle. Each recording electrode consisted of two silver-silver chloride one centimetre diameter electrodes embedded in an epoxy-mounted pre-amplifier system. The electromyographic signal was high pass filtered (40 Hz), further amplified, RMS processed and low passed filtered (400 Hz). Processed signals were sampled on-line at a rate of 1000 Hz for one second.

The experiment was started with the compressed air tank lying on its side on the floor. Subjects were asked to begin the experiment with bent knees, without raising the heels from the floor, and to pull the tank into a neutral carrying position next to their side as rapidly as possible without a jerking motion (Figure 1).

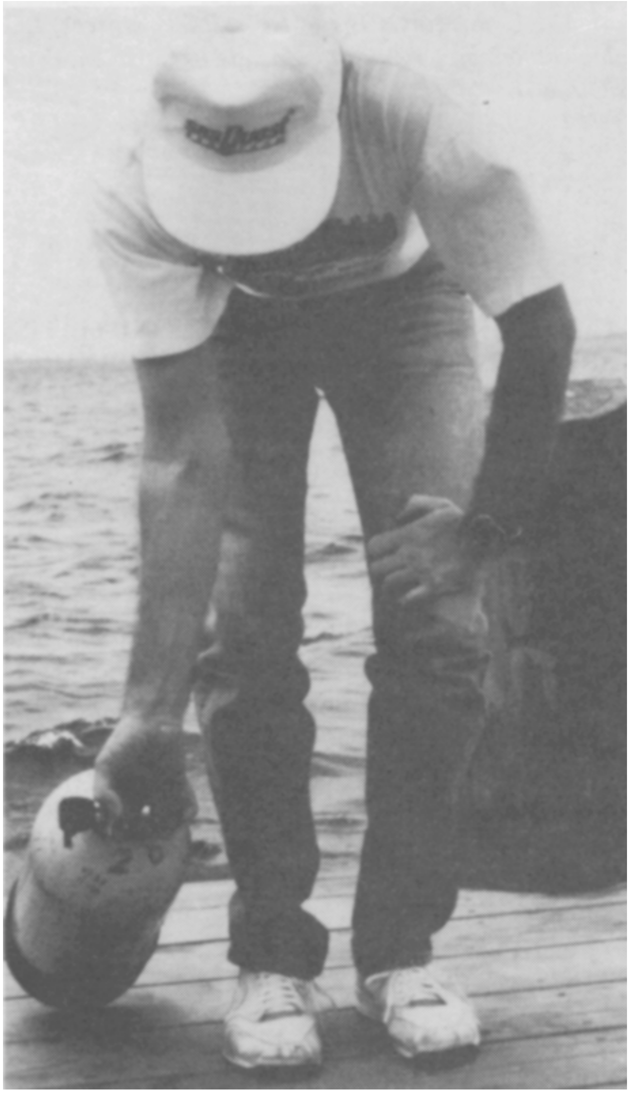

Figure 1. The position for lifting used in this study.

Random sequencing was used to perform sixteen separate lifting trials using four hand grips. The first grip (split hold grip) consisted of grasping the tank by the on/off knob and having the valve neck located between the index and middle fingers (Figure 2). The second grip (single grip) consisted of grasping the tank valve by the on/off knob with all fingers located on the knob side of the valve (Figure 3). The Tank Handle[2] (Figure 4) was utilized because of the sloping sling design for the third hold (sling grip). The Standard Tank Carrier No. TA-10[3] (Figure 5) was utilized for the classic baggage-style handle design for the fourth hold (H grip).

Data analysis consisted of normalization to the split hold grip RMS data which was given a value of one (Figures 6 and 7). The data is described according to percentage

Figure 2. Split hold grip.

Figure 3. Single grip

change in muscle activity (RMS) between the different groups.

Results

Analysis of the electromyographic activity revealed a biphasic curve with peak activity of the common extensor muscle group in early lifting which decreased when the neutral carrying position was achieved. The peak activity for the biceps muscle was achieved in the neutral carrying position after a delayed onset. With the use of the single grip there was more activity in both the extensor muscles and the

Figure 4. The tank handle

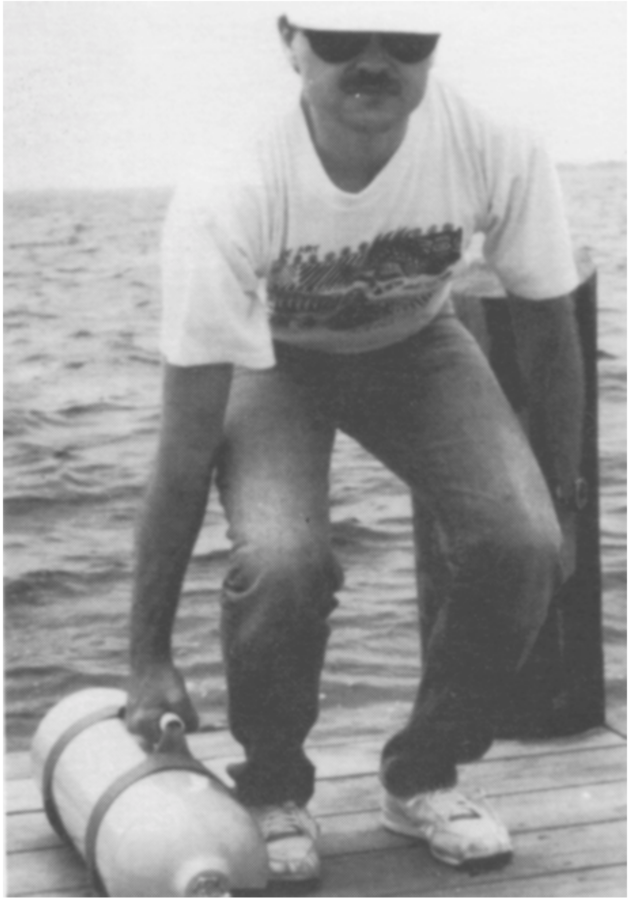

Figure 5. Standard Tank Carrier

biceps when compared to the split hold. However, both the extensor muscle group and the biceps demonstrated a dramatic decrease in activity with the use of either the sling tank carrier or the H style tank carrier.

In normal subjects, use of the sling grip resulted in a 45% decrease in extensor muscle group activity and a 61% decrease in biceps activity. With the use of the H grip, the extensor muscle group activity decreased 33% and the biceps activity decreased 52%. The H strap was least effective in the shorter subject who demonstrated only a 10% decrease in the extensor muscle group activity and a 13% decrease in the biceps. In the symptomatic subject, the sling strap was less effective than the H strap with only a 17% decrease in extensor muscle activity and a 65% decrease in biceps activity.

Discussion

The biomechanical actions implicated in the formation of lateral epicondylitis are the combination of wrist pronation with dorsiflexion. In this position, the extensor muscle group functions as a forearm flexor. The most extreme example of this motion is seen in major league baseball pitchers as documented by slow motion photography of the pitch.[4] Decreased degrees of pronation and wrist dorsiflexion are combined in a variety of sports and occupational activities.[5] It is well-documented that tennis players who are not properly conditioned and abuse their arm are more likely to develop lateral epicondylitis than those who are pre-conditioned.[6]

It is the combination of unconditioned forearms and over use during dive trips that predisposes both recreational and research divers to the formation of lateral epicondylitis. Our experiment demonstrates that wrist dorsiflexion is necessary in order for the average person to carry an A180 tank by their side. Shorter subjects may require elbow flexion to keep the bottom of the tank off the ground (Figure 8). Depending on the tank hold used, there is a variable amount of pronation required for tank lifting.

We have shown that both the common extensor muscle group and the biceps muscle group demonstrate decreased activity when carrier straps are utilized for tank handling because of less pronation. The exact reason why the sling strap was slightly more effective at decreasing muscle activity than the H style strap is uncertain. Perhaps the strap slope allows for better distribution of the weight to all of the muscle groups of the forearm.

Physicians involved in scuba diving activities, either as a consultant or as a diver should be aware of the risk of cumulative epicondylar injury which may be caused by improper tank handling.[1] A pre-dive training program involving both isometric and weight-bearing exercise combined with the active use of tank carrier straps during dive excursions may decrease the risk of injury.[6]

Conclusion

We have demonstrated a biomechanical rationale for the formation of lateral epicondylitis with the carrying of compressed air tanks. Lifting the tank requires both wrist dorsiflexion and pronation of varying degrees dependent on subject height and the grip used. These are the mechanisms

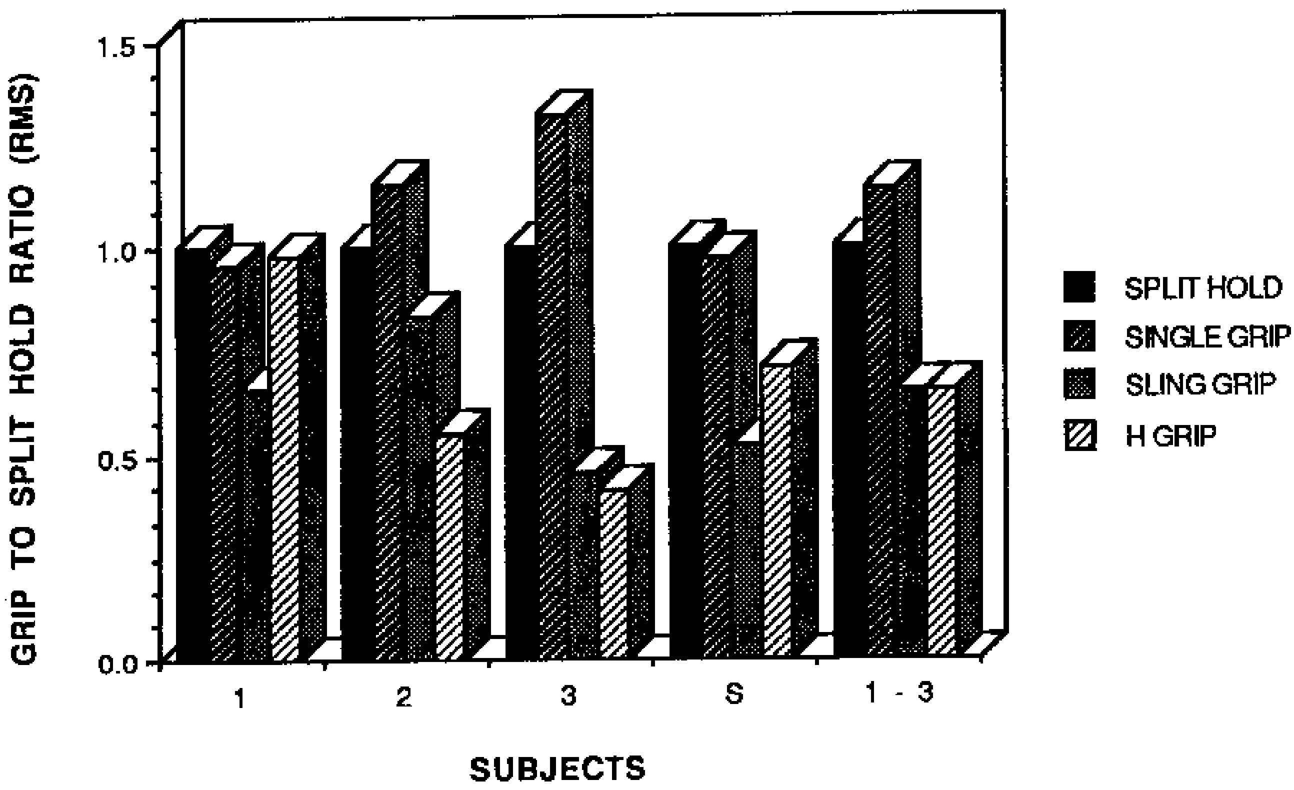

Figure 7. Effect of various tank grips on percentage change in muscle activity (RMS) for the common extensor muscle group of the forearm (split grip activity normalised to one).

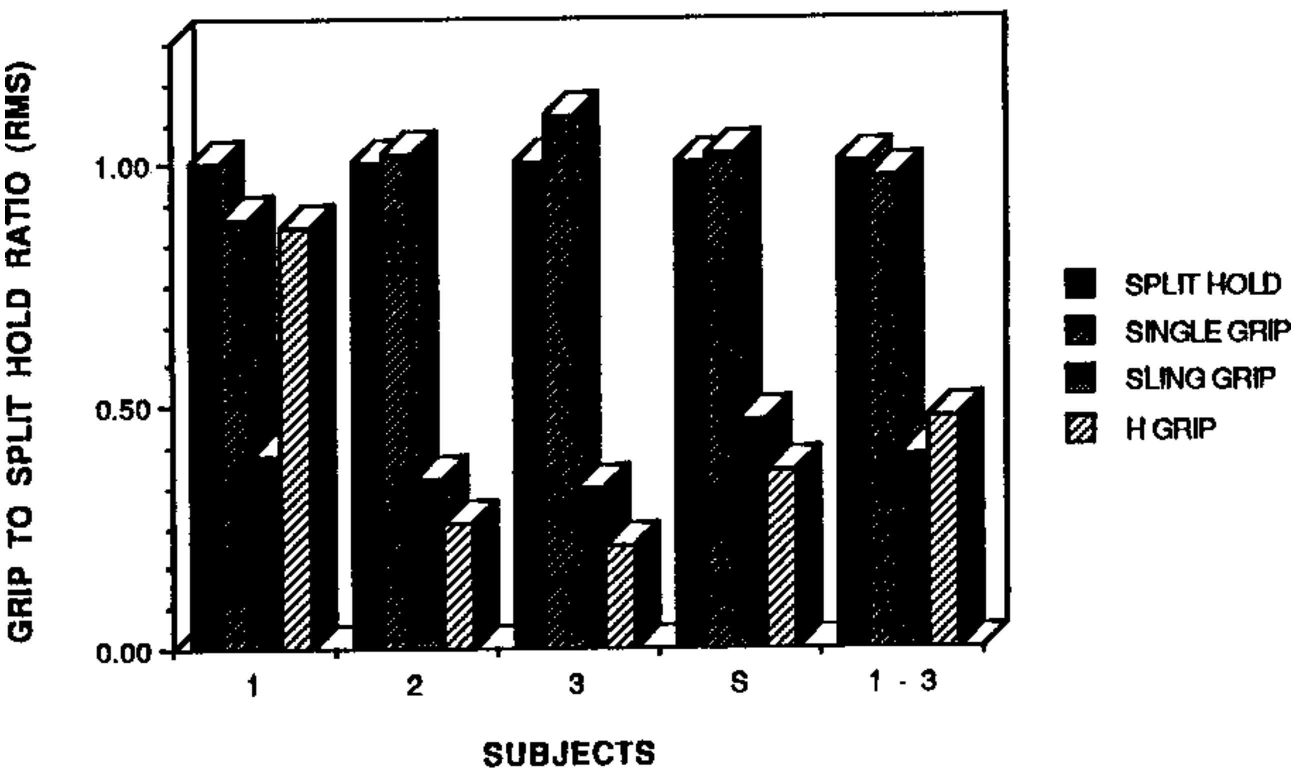

Figure 6. Effect of various tank grips on percentage change in muscle activity (RMS) for the biceps brachii muscle (split grip activity normalised to one).

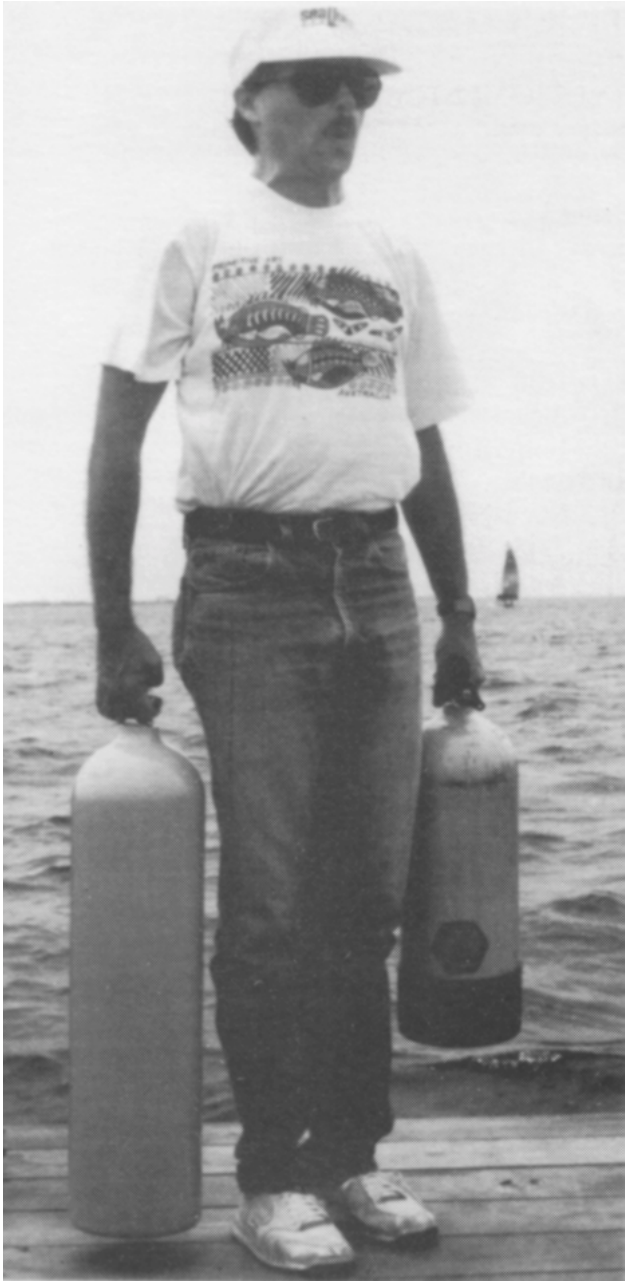

Figure 8. showing typical tank carrying posture.

which predispose humans to the formation of lateral epicondylitis. The use of tank carrier straps decreases the amount of activity of the forearm extensors and the arm flexors because less pronation is required. We recommend that dive physicians recognize tank carrying as a predisposing factor toward the formation of lateral epicondylitis. Active encouragement of patients to precondition the arm prior to dive excursions and the use of tank carrier straps may decrease long term disability.

References

2 Manufactured by Silent World Products, 5842 S.W. 32 Street, Miami, Florida 33155.

3 Manufactured by Trident Diving Equipment, 20842 Prairie Street, Chatsworth, California 91311.

4 King JW, Brelsford HJ and Tullos HS. Analysis of the pitching arm of the professional baseball pitcher. *Clin Orthop* 1969; 67: 116-123.

5 Gore RM, et al. Osseous manifestations of elbow stress associated with sports activities. *Amer J Radiol* May 1980; 134: 971-977.

6 Nirschl R.P. Tennis elbow. Symposium on sports injuries. *Orthop Clin North Am* 1973; 4: 787-800.

1 Barr LL and Martin LR. Tank carrier's lateral epicondylitis: Case reports and a new cause for an old entity. SPUMS J 1991; 21 (1): 35-37

Dr. Lori L. Barr is an Assistant Professor of Radiology and Pediatrics, University of Cincinnati, Children's Hospital Medical Centre, Cincinnati, Ohio 45229-2899, U.S.A.

Dr. D. Brunt is a member of the Department of Physical Therapy, Box J-154, Health Science Centre, University of Florida, Gainesville, Florida 32610-0154, U.S.A.

Mr. L.R. Martin is the Dive Safety Officer, LGL Ecological Research Associates, Inc., 1410 Cavitt St., Bryan, Texas 77801, U.S.A.