0363-5465/96/2424-0535$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, Vol. 24, No. 4

— Relatively no new information
— How do they know a strength program is required, just because these muscle are active does not mean they need to be strengthened.

Dynamic Electromyographic Analysis of Trunk Musculature in Professional Golfers

Robert G. Watkins,*† MD, Gurvinder S. Uppal,‡ MD, Jacqueline Perry,§ MD, Marilyn Pink,|| MS, and Jocylane M. Dinsay,* RN

*From the *Kerlan Jobe Orthopaedic Clinic, Los Angeles, the ‡Inland Empire Spine Institute, Riverside, §Rancho Los Amigos Hospital, Downey, and the ||Biomechanics Laboratory, Centinela Hospital Medical Center, Los Angeles, California*

ABSTRACT

Using dynamic surface electrode electromyography, we evaluated muscle activity in 13 male professional golfers during the golf swing. Surface electrodes were used to record the level of muscle activity in the right abdominal oblique, left abdominal oblique, right gluteus maximus, left gluteus maximus, right erector spinae, left erector spinae, upper rectus abdominis, and lower rectus abdominis muscles during the golfer's swing. These signals were synchronized electronically with photographic images of the various phases of the golf swing; the images were recorded in slow motion through motion picture photography. The golf swing was divided into five phases: take away, forward swing, acceleration, early follow-through, and late follow-through. Despite individual differences among the subjects' swings, we observed reproducible patterns of trunk muscle activity throughout all phases of the golf swing. Our findings demonstrate the importance of the trunk muscles in stabilizing and controlling the loading response for maximal power and accuracy in the golfer's swing. This study provides a basis for developing a rehabilitation program for golfers that stresses strengthening of the trunk muscles and coordination exercises.

Golf has become a very popular sport for men and women of all ages. Traditionally, the opinion has been that golf is not a vigorous sport and that preplay training is therefore not as important for golfers as it is for athletes involved in contact sports. A preplay flexibility and warm-up regimen is seldom employed by golfers at the amateur level. This may explain the high rate of injury among golfers who lack adequate trunk strength, coordination, and flexibility. As Batt[2] has written in his overview of golfing injuries:

> Golf cannot be considered as a particularly demanding sport either aerobically or anaerobically; however, to play well requires considerable skill and practice. Injuries occur, and result from a combination of factors including the age of participants, poor technique and overuse. The increased popularity of the game has led to an increase in the number of golf-related injuries and an increased awareness of their occurrence.

We have treated many golfers, both amateur and professional, for back pain, and we have noted that golfing produces tremendous stresses in the spine. Despite the significant prevalence of back pain among golfers at all levels of ability, the current literature does not fully address the importance of trunk muscle testing in golfers. To identify a reproducible pattern of trunk muscle activity during the professional golfer's swing, we sought to determine which trunk muscles were active during the different phases of that swing.

MATERIALS AND METHODS

Thirteen right-handed professional male golfers underwent EMG activity amplitude evaluation using surface electrode telemetry of the following trunk muscles: right erector spinae, left erector spinae, right upper gluteus maximus, left upper gluteus maximus, right abdominal oblique, left abdominal oblique, upper rectus abdominis, and lower rectus abdominis.

Each golfer was asked to warm up and take several practice swings before the study. Surface electrodes were then placed by a physical therapist with the aid of computerized telemetry evaluation. Correct electrode placement was confirmed through resting and maximal manual muscle testing (MMT) of each muscle. The signals from

† Address correspondence and reprint requests to Robert G. Watkins, MD, Kerlan Jobe Orthopaedic Clinic, 501 East Hardy Street, 300, Los Angeles, CA 90301.

No author or related institution has received any financial benefit from research in this study.

the leads were transmitted using an FM telemetry system (Model 4200-A, Biosentry Telemetry, Torrance, California). The subjects wore battery packs that powered the FM transmitter, with the pack oriented in such a way as to prevent bodily restrictions.

Each golfer took additional warm-up swings until he felt comfortable and was then asked to swing as he normally would, relying on his understanding of his own biomechanically "perfect" swing. Each golfer performed four trials. Two 16-mm high-speed motion picture cameras (Model DBM-55, Teledyne Camera Systems, Arcadia, California), operating at 45 frames per second, were positioned for superior and anterior views to record the subject's performance. The processed film was then examined and the swings were divided into five segments: take away, forward swing, acceleration, early follow-through, and late follow-through (Fig. 1).

The take away phase represents the interval from ball address to the completion of the backswing motion. The forward swing phase represents the interval from the completion of the take away to the point where the golf club is horizontal to the ground on the downward thrust of the club. The acceleration phase represents the interval from the previous phase to ball contact. Early follow-through represents the interval between ball contact and the point where the club is again horizontal to the ground, but this time on the upward swing. Lastly, late follow-through represents the interval from the horizontal club position to the completion of the swing.

The EMG recordings during the golf swing motion were converted from analog-to-digital signals by a computer (PDP-11/2/3, Digital Equipment Corp., Bedford, Massachusetts) at a sampling rate of 2500 Hz. After excluding the noise identified by the resting recording, the peak 1-second EMG signal during manual muscle strength testing was selected as a normalizing value (100% MMT). Activity patterns were assessed every 20 ms and expressed as a percentage of the normalizing value. These trunk muscle activity patterns were synchronized with the film record of the golfer during the swing to obtain percentage muscle activity values expressed as percentages of maximal muscle strength at each phase of the swing.

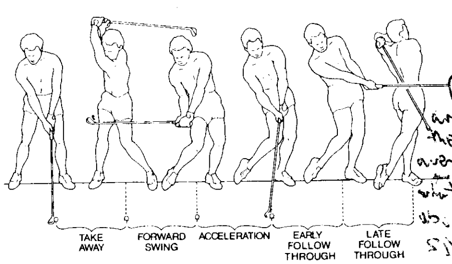


Figure 1. Phases of the golf swing (Reprinted with permission from Jobe et al.[5]).

RESULTS

Because the golfers all played right handed, the take away phase represents a clockwise rotation of each subject's torso. The large standard deviation among the golfers in muscle activity recorded during each phase of the golf swing is a phenomenon commonly encountered in EMG studies. This is why only reproducible trends in muscle activities during the phases of the golf swing rather than absolute numbers were analyzed.

The abdominal oblique muscle showed activity in all phases of swing, and there was equivalent activity in both the right and left sides during take away. During the forward swing, there was only slightly less activity in the right side compared with the left. During acceleration and early follow-through, there was considerably more muscle activity in the right than the left side; a difference that was eliminated during late follow-through, when the two sides had equivalent activity.

The upper and lower rectus abdominis muscles had very similar activity during the majority of the swing. The lower portion had more activity during take away and late follow-through. The activity of this muscle increased with the progression of the swing until it reached its zenith during the acceleration phase, then began dropping and continued to decline through the late follow-through phase.

Activity in the right erector spinae muscles increased from the take away, reaching its maximum at forward swing, after which it began to fall at late follow-through. The pattern of activity of the left erector spinae muscle was similar to that of the lower rectus abdominis muscle, i.e., its activity increased steadily during the initial phases, with its maximal value reached during the acceleration phase. After that, it declined through the late follow-through phase.

The activity of the right gluteus maximus muscle produced a relatively low baseline during all swing phases except for a spike during the forward swing phase. The left gluteus maximus muscle had an activity pattern similar to the left erector spinae and the lower rectus abdominis muscles, i.e., activity increased as the swing progressed, with the maximum reached during the acceleration phase and subsequently declining up to the late follow-through phase.

Of all phases of the swing, it was during take away that the trunk muscles showed their lowest amount of activity. The right and left abdominal oblique muscles had 23% MMT and 24% MMT activity, respectively, and the upper and lower right rectus abdominis muscles had 4% MMT and 13% MMT activity, respectively. The right and left gluteus maximus muscles had 15% MMT and 11% MMT activity, respectively, and the right and left erector spinae muscles had 16% MMT and 26% MMT activity, respectively.

During the forward swing, there was greater overall trunk muscle activity. The right and left abdominal oblique muscles had 52% MMT and 63% MMT activity, respectively. There was pronounced right gluteus maximus muscle activity of 84% MMT; however, the left gluteus maximus muscle had 35% MMT activity. The right and left erector spinae muscles had 55% MMT and 35% MMT activity, respectively, and the upper and lower right rectus abdominis muscles had 30% MMT and 31% MMT activity, respectively.

During acceleration, the right and left abdominal oblique muscles had 59% MMT and 38% MMT activity, respectively. The right and left gluteus maximus muscles had 21% MMT and 53% MMT, the right and left erector spinae muscles had 38% MMT and 44% MMT, and the upper and lower rectus abdominis muscles had 35% MMT and 34% MMT, respectively.

During early follow-through, the right and left abdominal oblique muscles had 51% MMT and 38% MMT activity, respectively. The right and left gluteus maximus muscles had 14% MMT and 33% MMT, the right and left erector spinae muscles had 19% MMT and 31% MMT, and the upper and lower rectus abdominis muscles had 21% MMT and 28% MMT.

During late follow-through, the right and left abdominal oblique muscles had 34% MMT and 39% MMT activity, respectively. The right and left gluteus maximus muscles had 8% MMT and 14% MMT, the right and left erector spinae muscles had 15% MMT and 19% MMT, and the upper and lower rectus abdominis muscles had 9% MMT and 16% MMT.

DISCUSSION

Knowledge of the dynamic interactions that the spine and the affected muscles undergo during vigorous sports activities has aided us in rehabilitating athletes with injured backs. More specifically, it has been instrumental in giving us insight into the importance of building and, when impaired by injury or overuse, regaining trunk muscle strength and coordination. This holds true even in those sports for which we previously believed that strains were predominantly confined to the upper extremities. One such sport is golf. Contrary to the popular belief that 18 holes of golf represents less danger of damage to the back than trimming an average-sized lawn with a power mower, we have found that the golf swing produces tremendous stresses in the spine.

Most golf injuries arise from overuse and are generally localized to, in order of frequency, the wrist, back, elbow, and shoulder. They are a function of the age of the golfer, the golfer's skill, and the amount of play. In a survey of those athletes who spend the most time on the links, golfers on the professional tour, nearly 60% of those who had been injured reported they were still troubled by their injuries.[9] The Tournament Player's Association estimates that between 10% and 33% of touring professionals are playing injured at any one time. This is not surprising considering that if professional golfers do not work, even when in pain, they have no income. They have neither sponsors nor athletic teams to pay them a salary, provide them medical insurance, or grant them paid sick leave.

Studies have shown that there are risk factors inherent in the golf swing, particularly for the older golfer[3,8] and the beginning golfer. For example, Koslow,[7] in looking at weight-shift patterns among 30 beginning golfers while swinging a golf club, found that when swinging an eight-iron, 22 golfers, and 25 while using a driver, displayed patterns that failed to conform to commonly prescribed patterns.

Electromyographic evaluation of upper extremity muscle activity during baseball, tennis, swimming, and golf has previously been described.[4,5,7,11-14] Dynamic EMG recordings of professional baseball pitchers have been used to demonstrate a reproducible pattern of torque transfer in trunk muscles; a pattern that apparently directly affects the biomechanics of the throwing arm, which control the stabilization and loading responsible for maximal power and control.[5] Electromyography has also been used in quantitative studies of back muscle activity.[1,10]

CONCLUSIONS

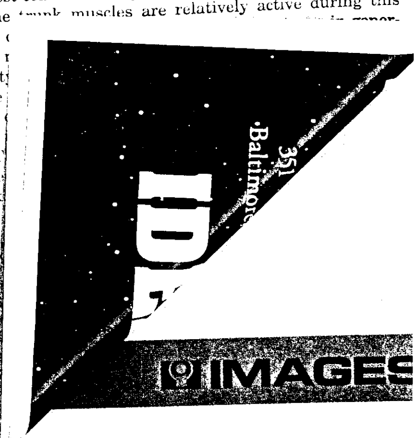
This study used EMG to demonstrate the activity of trunk muscles in professional golfers. This testing demonstrated a relatively consistent pattern of muscle activity:

1. Muscle activity levels during the take away phase are relatively low. The higher activities are in the trailing erector spinae and both abdominal oblique muscles. This phase, in which the golfer is preparing for the swing, is considered the least strenuous.

2. During the forward swing, the high level of activity of the gluteus maximus muscle, especially the trailing right side, indicates the role of the hip stabilizers and the initiation of power to start the drive of the golf club into the acceleration phase. The highest muscle activity throughout the swing is expressed in this hip stabilizer during this phase. This is consistent with the shifting of the center of mass toward the left side as the golfer begins to accelerate the golf club with the force necessary to drive the golf ball the greatest distance (force = mass × acceleration). The erector spinae and abdominal oblique muscles also show significant activity during this phase, indicating their importance during the forward swing.

3. The acceleration phase of the golf swing requires the greatest conversion of potential energy to kinetic energy. All the trunk muscles are relatively active during this phase ... ating ... activit... in the ... effect ... effect ...

4. T... accele... trunk ... than ... lique ... the a... cle is ... less ... left a... of th... rema... follo...



5. In the follow-through phase, the trunk is decelerating. Generalized trunk muscle activity continues to decrease. Notably, the activity in the left abdominal oblique muscle remains the same as during the previous phase, but the activity in the right abdominal oblique muscle becomes less than that of the left. The importance of the abdominal oblique muscles during the follow-through periods suggests their role in decelerating the trunk after the swing.

Patterns of muscle activity translate to muscle coordination, and even though there is great variation in the patterns of swing, the reproduction of a consistent firing sequence demonstrates this coordination. Less experienced golfers tested with this method may have a greater variety of muscle firing sequences. Also, the muscle firing sequences in injured players may be different from those in the uninjured player. Thus, this technique may represent a potential tool for evaluating certain muscle injuries.

This study demonstrates that trunk muscle strength is certainly important and trunk coordination is vital to both the professional or recreational golfer. It points out the need for a trunk strengthening program for injured golfers that is oriented toward balance and coordination. As a result of studies of this kind, our treatment programs for golfers with back injuries have been further developed and modified to include not only trunk strengthening but also a treatment plan to enhance trunk coordination.

REFERENCES

1. Andersson GB, Ortengren R, Herberts P: Quantitative electromyographic studies of back muscle activity related to posture and loading. *Orthop Clin North Am 8:* 85–96, 1977
2. Batt ME: Golfing injuries: An overview. *Sports Med 16:* 64–71, 1993
3. Ekin JA, Sinaki M: Vertebral compression fractures sustained during golfing: Report of three cases. *Mayo Clin Proc 68:* 566–570, 1993
4. Glousman R, Jobe F, Tibone J, et al: Dynamic electromyographic analysis of the throwing shoulder with glenohumeral instability. *J Bone Joint Surg 70A:* 220–226 1988
5. Jobe FW, Perry J, Pink M: Electromyographic shoulder activity in men and women professional golfers. *Am J Sports Med 17:* 782–787, 1989
6. Jobe FW, Schwab DM: Golf for the mature athlete. *Clin Sports Med 10:* 269–282, 1991
7. Jobe FW, Tibone JE, Perry J, et al: An EMG analysis of the shoulder in throwing and pitching. A preliminary report. *Am J Sports Med 11:* 3–5, 1983
8. Koslow R: Patterns of weight shift in the swings of beginning golfers. *Percept Mot Skills 79:* 1296–1298, 1994
9. McCarroll JR, Gioe TJ: Professional golfers and the price they pay. *Physician Sportsmed 10(7):* 64–70, 1982
10. Morris JM, Benner G, Lucas DB: An electromyographic study of the intrinsic muscles of the back in man. *J Anat 96:* 509, 1962
11. Morris M, Jobe FW, Perry J, et al: Electromyographic analysis of elbow function in tennis players. *Am J Sports Med 17:* 241–247, 1989
12. Perry J, Pink M, Jobe FW: The painful shoulder during the backstroke: An EMG and cinematographic analysis of 12 muscles. *Clin J Sports Med 2:* 13, 1992
13. Scovazzo ML, Browne A, Pink M, et al: The painful shoulder during freestyle swimming. An electromyographic cinematographic analysis of twelve muscles. *Am J Sports Med 19:* 577–582, 1991
14. Watkins RG, Dennis S, Dillin WH, et al: Dynamic EMG analysis of torque transfer in professional baseball pitchers. *Spine 14:* 404–408, 1989