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## **1. The 6 Physical Preparation Steps to a Successful Golf Day - Part 1**

**By Ramsay McMaster** ([golfphysio@golfmed.net](mailto:golfphysio@golfmed.net))

Many of the world's top tour players not only shoot great scores, they also have a regular routine on competition days. This is in stark contrast to the average golfer who has high expectations on competitions but is often poorly or inadequately prepared.

Think back to your last few competition rounds. Did you do the same thing before, during and after the round? Or did you jump out of bed, into the car and off the course one week but mowed the lawn, drove to the course and stood around chatting the next week? Or do you rush to the first tee from the office, have a practice swing and slap it out of bounds?

Generally time management among club golfers is very poor. If your routine is scattered you'll be undercooked by the time it's your turn on the first tee and chances are your score will suffer. Managing your time will mean there is no rush to the golf course, reducing tension and anxiety levels and a more fluent and effective routine which will maximise your ability once on the course.

Following is a six-step strategy to enhance your performance on your golf day. This strategy may take time to organise, but if you stick at it for four weeks, you will maximise your potential to save shots on your golf day.

## **Step 1 – Leaving Home**

### **A. Check the Weather**

This is the first strategic part of preparation, especially if you are unfamiliar with the course and the variable weather elements. The easiest way is to check the local papers, look on the internet, check local media or call up your local golf professional. While you're on the phone find out if there are any delays for your scheduled tee-off time and they may also be able to give you strategic tips for that day: speed of the greens, direction of wind, tough pin placement etc. This allows you to be more mentally prepared prior to your arrival.

#### **For Warm Weather Think:**

- Water bottle—fluids
- Sunscreen and sunglasses
- Umbrella—shade
- Extra glove
- Adhesive to ensure grips stay tacky when your hands are sweaty
- Dress shorts instead of slacks
- Change of socks

#### **For Cold Weather Think:**

- Warm clothes
- Beanie and long johns - keeps core body temperature warm, relieving muscle tightness
- Change of socks
- Check spikes in case of slipping
- Dried fruit, nuts, sandwiches, small flask

### **B. Check your Equipment**

- Clean your clubs—your weapons are now ready for battle.
- Check golf balls. Familiarise what type of ball you will select—distance, spin etc.

### **C. Stretches and Exercises**

In the morning you can make a choice of some basic exercises that cover you from head to toe. As long as you select the drills that you feel are most effective, you can mix and match as you see fit. For more golf-specific exercises contact [www.golfmed.net](http://www.golfmed.net)

## **Step 2 – Getting There**

Many golfers travel as a group or individually by car. However most do not plan a strategy to minimise the physical discomforts of car travel.

### **Problems**

- Poor seats and prolonged sitting either as a passenger or as a driver will cause bad posture resulting in stiffness of spine, shoulders and neck
- Long periods driving may result in tightness in the hamstrings and the muscles of the forearms and the hands
- Intense brightness or sun glare can affect vision
- Mental fatigue is common with long periods of concentration behind the wheel and likely to affect performance
- On long journeys golfers can't exercise so energy requirements are lower
- You may be tempted to over eat because of boredom
- You may under eat because of lack of appetite stimulation
- You may arrive at destination for tournament with depleted glycogen stores
- You'll probably feel fatigued, stiff and sore from sitting down for hours

### **Solution**

- Organise a roster so that each person can share a part of the driving if travelling a long distance
- If travelling a long distance take time to stretch at driver change overs - this will break up the fixed sitting position
- Stop at a park if possible to go for a walk and a stretch. This is much more pleasant than roadhouses
- Try to maintain good sitting posture while travelling. Use a lumbar roll to support your back and try to keep your knees at 90 degrees to your hips

**Solution continued**

- Wear good quality sunglasses to reduce the intensity and glare of the Australian sun
- Play relaxing music or music that you enjoy to promote a calming effect
- Plan the best route and arrive ahead of time to prepare your pre-tournament regimes
- If you're talking on a mobile phone use a handset—this will reduce neck tension. Even better, turn the phone to message bank to get your mind away from work on the way or at the course
- Take an esky, fill it with healthy food eg. sandwiches, fruit, yogurt etc
- Take a thermos of nourishing soup or hot water to make your own drinks
- Take low fat, high carbohydrate snacks to maintain glycogen stores
- Try to stick to normal meal times and don't over or under eat.
- Suck on lollies or chew gum in preference to chips or other high fat snacks (a few won't hurt)
- Stop and stretch every two hours so you don't become fatigued and use food to compensate

### **Step 3 – Arriving**

Most golfers incur their first golf injury before they even leave the car park. This is caused by:

#### **Problem**

- Not being aware of the change in body temperature when exiting the car, for example air conditioning in summer, heater on in the winter. Heat and cold will cause changes in the muscle tissue and may lead to injury as a result of the temperature difference
- Trying to pull or drag golf equipment from the backseat into the passenger and driver seats
- Poorly lifting and handling equipment as you removed it from the boot of the car

#### **Solution**

- Always stretch and check your range of movement slowly when getting out of the car
- Use your legs when lifting or dragging your equipment out of the car

**The final 3 steps will appear in our next issue.**

**If you would like to receive a full colour copy of the “6 Physical Preparation Steps” in Acrobat PDF format, contact Ramsay McMaster via email at [golfphysio@golfmed.net](mailto:golfphysio@golfmed.net)**

## **2. Effects of excessive training loads on junior and sub elite golfers without golf specific exercise programs**

**By Denis McDade**

Head Coach VIS Golf Program  
AAA Member PGA of Australia  
Grad Dip Sports Coaching

Due to the ever increasing prize money on offer on PGA Tours of the world and the influence on the game Tiger Woods early career success has had, we live in an age where junior golfers and parents seem to feel that they are in a race against time to get on tour. As a consequence, an increasing number of parents and coaches are prescribing practice and competition loads that don't take into account the need for a golf specific physical preparation program, and in doing so expose developing bodies to inappropriate physical loads, having a detrimental effect on their rate of development.

Early years should be spent forming a love for the game and being introduced to the training components upon which long-term success are built, namely technical, tactical, physiological and psychological competency. For example, acquiring basic visualization and proprioceptive ability via fun psych drills and golf specific exercise can equip juniors with skills that will speed the rate of technical improvement, as well as enhance competition performance.

Obviously, juniors need to have instilled into them a strong work ethic and understand that many years are required for clumsy, unreliable swings to mature into reliable, efficient motions, but also that their work ethic be applied to all training components.

Golf injury can manifest itself in a number of ways, most commonly in the form of overuse-related restriction of range around joints that makes technical change difficult to achieve or sustain. This is the area that affects so many juniors. They spend years hitting balls with little or no attention to golf specific exercise and specialize in golf at an early age, so that the counteracting effects of cross training in other sports are lost. The cumulative effect of these factors, along with hours spent in poor postural positions doing homework, using computers, watching television and a more sedentary lifestyle in general are considerable, our research over 10 years showing that large percentages of juniors have chronic injury at an early age.

The problem for junior golfers gets to critical stage as they gain entry into elite programs such as the Victorian Institute of Sport Golf Program. The problems created by training loads that are too heavy due to lack of corrective physical programs as juniors combined with a more sedentary lifestyle leaves the sub-elite golfer in a position where they find it difficult to increase training load without breaking down through acute injury. Typically, the golfer would like to take on the training workload and associated intensity of an elite player but cannot. In addition, the player has to deal with the fact that he or she has trained inefficiently for years, dysfunction and/or injury exist as a result, and sustained improvement from this point will require a decreased amount of practice and an increase in corrective golf specific exercise. This process of course slows their rate of development and subsequently the amount of time it will take to progress through to Tour level. The massive culture change and time required to correct past 'sins' can be a bitter pill for the young golfer to swallow.



There are many others effects of overuse injury. Side-effects ranging from actual physical breakdown and therefore inability to practice have already been discussed, but shortened playing careers, careers that never get off the ground in the first place, athlete and coach frustration at the inability to change or sustain technique changes, and the mental mindset that 'I can't change' all have a bearing on the careers of our young players.

It is vital that juniors and sub-elite players have an understanding of the impact of golf upon their bodies communicated to them as beginners. In the past, golfers seem to have considered physical preparation and other training factors as performance enhancers for the elite player to explore. All training factors should be an integral part of the programs of our young golfers. This is the level where the culture-change needs to occur, and career-enhancing habits will be formed. Sub-elite golfers may then be able to enter elite programs with a low occurrence of injury and be able to progress through these programs onto the world stage at an earlier age, with the prospect of a body that has some chance to standing up to the rigors of a long playing career. Together as a coach and sports science community we have a responsibility to impart this vital message to our young golfers.

### 3. Train Your Brain

By Karl Morris ([rkkmorris@hotmail.com](mailto:rkkmorris@hotmail.com))

Training your golf brain should be viewed in the same manner as you would look at embarking upon a new training regime or a specific area of technical change within your swing.

Mental training is not an instant fix or a panacea for all ills, yet with a systemised approach and a long-term commitment it can be the missing link in your quest to fulfil your potential as a player.

Training your golf brain alongside training your body and your golf swing will allow you to become as good a player as it is possible for you to be.

When we work with any player we break down the whole area of mental training into 4 key quadrants.

- Before Golf
- During Golf
- The 'In Between'
- After Golf

In one of 4 quadrants each player will find the ONE key area of weakness to work on that will provide the LEVERAGE for the rest of the game to start to improve. (for the full systemised programme go to [www.golf-brain.com](http://www.golf-brain.com))

Visualisation is probably THE most misunderstood and badly used of all the mental training tools.

Most people think of mental training as visualisation and positive thinking, that is a bit like saying there are two types of wine....red and white...and that's it!. As we become more aware of the tools available to us we recognise the subtleties required to allow maximum benefit to be gained by the individual from mental coaching.

Visual imagery (visualisation) is frequently recommended by sports psychologists to help golfers maximise performance.

Just as a specific type of instrument is recommended by a surgeon for a given purpose, so should the sports psychologist recommend a specific type of visualisation for a given purpose.

All too often, however visualisation is recommended in a very non-specific way. Sometimes even the most basic specification- that is disassociated verses associated, is not made.

For example it might be recommended that you visualise yourself driving . . . Given this recommendation, should you imagine seeing yourself on a screen as though you were watching a movie of yourself(a disassociated visualisation) or should you actually be in the imagined scene, actually looking through your own eyes and feeling your feet on the grass(an associated visualisation)?

Since both tools are very valuable in different ways, this is an essential specification.

Once this essential specification is determined, adjustments are needed. In the same way that the specific instrument must be tailored and adjusted to the operation at hand, so does the specific visualisation need to be tailored and adjusted.

For example whether associated or disassociated, is the scene to be imagined in black and white or in colour? If in colour, is the colour bright or dull? What happens when you reverse the action or speed it up.

These questions reflect some of the possible adjustments that can be made regarding how we visualise, the way that we go about this process will greatly influence the results we achieve.

For me personally, I feel that the potential that we have at our fingertips with these techniques particularly in the area of swing change is enormous. The reason that people do not sometimes respond well to video work and so many who seem unable to change a particular motion in their swing can in many instances be attributed to how they “represent” the information to themselves in their own mind.

Some of the techniques that you can learn will be of enormous benefit to your game.

A professional that I had been working with had always had great difficulty in visualising any form of outcome with regards to a shot. He had read various books detailing the importance of ‘seeing the ball flight’.

*“The more I try to force the image of the shot the worse I play. The best I do is see a fuzzy image of the ball flight”*

We did some work together and discovered that he was an extremely auditory person. All his language predicates pointed towards auditory modalities, I hear what you are saying, it sounds to me like, that rings a bell, where just a few of his regular phrases.

He constantly ran an inner dialogue about almost everything he did. During his shot routine we worked on him DESCRIBING internally the shot he wanted to play, in detail.

*"I am going to hit this at the left hand trap with a hint of fade to allow the ball to finish left side of the fairway"* is an example of what we did.

As soon as he started to describe the shots verbally he found that a visual image appeared of the shot that he wanted.

We had created a change by using his LEAD SYSTEM (auditory) to allow the visual system to kick in, rather than trying to fight his preferences and force the visual imagery.

This is true for a lot of players, you just need to do a little detective work to find out their preferred system and work with that rather than against it.

**Dr. Karl Morris**

Currently working with the English Ladies Golf Association as Golf Psychologist at national level, author of the book Masterstroke (mental techniques to improve golf) and soon to be published 'Golf Mind' currently working with the PGA of Great Britain on the Trainees' diploma course and the Continuing Professional Education programme.

Golf Psychologist to Today's Golfer, he runs a private practice working with players from the European Tour, Challenge Tour and Euro Pro tours.

Karl is a qualified Master Trainer of NLP and delivers training and performance coaching to the corporate sector. He is also a qualified PGA professional.

**For any more information or to contact**  
**www.golf-brain.com**

**or**

**Tel. 07889 - 249031**

## 4. Trainees – Our Futures in Golf

**By Shaheena Khan** ([gripphysio@optusnet.com.au](mailto:gripphysio@optusnet.com.au))  
**Sydney Golf Physiotherapist**

A 20 year old 3rd year trainee who is a right handed golfer presented with right shoulder pain. He had experienced pain and swelling for 2 months and did not recall any specific injury. He was unable to sleep on that shoulder for the past few weeks. Golf did not aggravate the pain, but he was having more difficulty controlling his club head at the end of his backswing. He had also started to develop lower back stiffness in the past few weeks. The young trainee also played indoor cricket and touch football as recreation.

His golf swing in the clinic exhibited limited external rotation of the right shoulder on backswing, with scapular winging and slight reduction of thoracic spinal rotation from T3 to T6. He said that his golf coach was trying to get him to keep his right elbow pointing down on the backswing and that this had become increasingly difficult.

Shoulder range appeared normal, with scapulo-humeral dysfunction through flexion and abduction. There were positive signs for biceps and rotator cuff impingement and tendonitis. Of more concern was a positive “empty can” test.

The trainee was questioned further regarding indoor cricket and we found that he had experienced pain and weakness with bowling and throwing the cricket ball. He was counselled regarding the possibility of a SLAP Tear (superior glenoid labrum), and the likelihood that cricket was the cause of this injury. He was referred to a shoulder specialist who confirmed the diagnosis through MRI. The specialist felt that surgery was not essential and encouraged conservative treatment, as well as withdrawal from cricket. We also felt that a two-week rest from golf would assist rehabilitation.

The trainee was agreeable to this plan, as this was a crucial and final year in the traineeship.

Treatment was directed at

- Reducing inflammation (5 days of NSAIDS, ice, ultrasound)
- Restoring muscle balance through deep tissue releases and specific rotator cuff and scapula stabilisation exercises.

Shoulder pain settled within six treatments over three weeks. He came in weekly for a further 3 weeks to progress the exercises. Cessation of throwing cricket balls would certainly have assisted his recovery.

Core stabilisation was incorporated into the program. The lower back stiffness was addressed with local treatment. Symptoms in the lower back did not recur. We felt that this was due to better core stability and restoration of sound swing mechanics. This was confirmed by his coach at a follow up lesson 4 weeks after treatment had commenced.

The trainee recovered enough shoulder stability to continue playing golf and successfully completed his traineeship. Symptoms had not reoccurred eight months later.

This is one of the many examples where a medical team can work with a golfer and their coach to assist a holistic approach to recovery from an injury.

## 5. Emotional Golf

By Pia Nilsson and Lynn Marriot ([news@coachingforthefuture.com](mailto:news@coachingforthefuture.com))

**Theme: Emotional Management... a learned process...**

**“Aware – Manage – Create... 7 Seconds to a Better Golf Game.”**

Golf and the holiday season have one thing in common for many people: emotional stress. We thought this theme could be a support for you both in golf and in preparing for the holidays.

If your holiday stress is really bad we recommend you read “Skipping Christmas” by John Grisham.

Emotions play a primary role in the development and function of the mind and body. Emotions clearly play a key role in the day to day experience and success of your golf game. Think of the last bad decision you made with a shot on the golf course. Did mismanaged emotions play a part in that decision? Did you overreact and make that decision based on a knee-jerk reaction after a previously missed shot?

Current research clearly indicates that performance is directly influenced by stress and emotional mismanagement. Research at the Institute of HeartMath suggests that emotional reactivity and stress, which we often experience as inner turmoil, can inhibit the cortical regions of the brain. With the cortical functions inhibited, problem solving is hampered, reaction speeds and coordination are impaired, and we cannot think as clearly. Decisions are less effective, our listening skills are impaired, and creativity is obstructed. It's true that anger makes us stupid!



Researcher and author Joseph Chilton Pearce says that when we become upset for any reason “all neural action, learning, memory, cognition, problem-solving, and so on are adversely affected.” Our emotional state is critical to what and how we learn and how well we can recall and apply what we learned. Built into the emotional-cognitive structures of the brain are many evolutionary functions that date back to our species struggle for survival and the mechanisms that evolved to cope with stress. Brain structures like the amygdala in the “emotional” or limbic region of the brain can “hijack” intellectual processes when intense emotions are experienced in the system. This is why every very smart people can make very foolish choices when under emotional stress.

So how does this relate to your golf? Every time you hit a golf shot... something happens. In reality the only thing that happens is that the ball goes somewhere.

We like to say the ball starts at one point and travels to another point. If the ball doesn't move then the result was a whiff!

Now what happens next (almost instantaneously in the brain) is some judgment of that reality. You either like where the ball went or you don't... thus some emotional reaction occurs. Based on those emotions and the resulting chemical flush you experience you either move your system towards a state of coherence or away from it.

We have all experienced moments of coherence when things seemed in sync, we were in “flow,” our actions and intentions matched, and the outcomes were productive, efficient and fulfilling. Coherence is the underlying principle of what makes a laser so powerful. A laser produces coherent light waves that are highly efficient. The shift from incoherence to coherence can bring dramatic effects: a 60-watt light bulb whose light waves can be made coherent as a laser, would have the power to bore a hole through the sun from 90 million miles away!

Coherence can be measured bio-medically. Internal coherence can be measured by monitoring the electrical synchronization of the brain and heart and determining whether the nervous system is “full of noise” or “static free.” Coherence is efficiency in action. Attention span, mental clarity, and creativity naturally increase. Power is maximized. Coherent human beings and golfers thrive mentally, emotionally, and physically.

So bottom line is... your emotional reaction after the shot determines if you are going to build up your reserves of coherence or deplete them. Your emotional judgment or reaction is a choice. It is a choice in perception.

Now what to do about it...

Go back to when the ball left the clubface and begins its journey forward... this is the precise moment of emotional management.

Stop any reaction you might have immediately... don't get caught up in where the ball is going and what it means to you... Just begin counting slowly to seven.

1 one thousand, 2 one thousand and so on...

In those seven seconds you can stop the emotional hijacking (the amygdala looking for an emotional match to a previous experience) and become conscious and neutral to the event.

You have created a space where you can consciously make a choice of perception.

You are aware... you are in management of your emotions.

Now create the emotion or judgment that best serves your future... for the next shot, the rest of the round or your golfing career.

We believe these seven seconds are one key to your reaching your greatest potential... your 54.

## 6. National Sports Information Centre

The National Sport Information Centre, a program of the Australian Sports Commission has an extensive collection of golf books, journals and videotapes.

Listed below are articles and research papers that may be ordered from the NSIC.

Order form and prices can be found at the website -  
<http://www.ausport.gov.au/nsic/docdel.html>

### Contact Details

#### National Sport Information Centre

Australian Sports Commission  
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Australia

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Internet: <http://www.ausport.gov.au/nsic/>

### Editorial: Science and Golf

Thain, E.  
Journal of Sports Sciences (London)

ISSUE: 20 8 Aug 2002 589

KEYWORDS: Golf | Congress | Sports Science

Introduces articles featured in the current journal volume, including topics on confidence building, deformation properties of club heads and golf balls, and other papers selected from the Fourth World Scientific Congress of Golf, July 22-26, 2002.

ACH-3308

**Bone mass, bone mineral density and muscle mass in professional golfers**

Dorado, C.  
Journal of Sports Sciences (London)

ISSUE: 20 8 Aug 2002 591-597

KEYWORDS: Golf | Body Composition | Densitometry | Muscle | Osteoporosis | Bone Density | Man | Professional | Non-athlete | Comparison Study

The aim of this study was to determine the effects of long-term professional golf participation on whole-body and regional bone mass and density. Dual-energy X-ray absorptiometry was performed on 15 male professional golfers and 18 sedentary individuals, matched for sex, race, age (29 +/- 1 and 25 +/- 1 years, respectively), body mass (79 +/- 2 and 74 +/- 2 kg), height (1.78 +/- 0.01 and 1.77 +/- 0.02 m) and percent body fat (20 +/- 2 and 21 +/- 2%; mean +/-sx).

We found that long-term professional golf participation is not associated with significant increments in regional or whole-body bone mass or density. Neither the lumbar spine nor the femoral neck showed any noticeable enhancement of bone mass in professional golfers compared with controls from the same population. The only effect of professional golf participation on regional body composition was a 9 % increase in muscle mass in the dominant arm (P < 0.05).

ACH-3309

**Comparison of spine motion in elite golfers with and without low back pain**

Lindsay, D.  
Journal of Sports Sciences (London)

ISSUE: 20 8 Aug 2002 599-605

KEYWORDS: Golf | Professional | Back | Pain | Posture | Address | Swing | Injury | Comparison Study | Man

Low back pain is a common musculoskeletal disorder affecting golfers, yet little is known of the specific mechanisms responsible for this injury. The aim of this study was to compare golf swing spinal motion in three movement planes between six male professional golfers with low back pain (age 29.2 +/- 6.4 years; height 1.79 +/- 0.04 m; body mass 78.2 +/- 12.2 kg; mean +/-s) and six without low back pain (age 32.7 +/- 4.8 years; height 1.75 +/- 0.03 m; body mass 85.8 +/- 10.9 kg) using a lightweight triaxial electrogoniometer.

We found that golfers with low back pain tended to flex their spines more when addressing the ball and used significantly greater left side bending on the back swing. Golfers with low back pain also had less trunk rotation (obtained from a neutral posture), which resulted in a relative 'supramaximal' rotation of their spines when swinging. Pain-free golfers demonstrated over twice as much trunk flexion velocity on the downswing, which could relate to increased abdominal muscle activity in this group. This study is the first to show distinct differences in the swing mechanics between golfers with and without low back pain and provides valuable guidance for clinicians and teachers to improve technique to facilitate recovery from golf-related low back pain.

ACH-3310

**The effects of outcome imagery on golf-putting performance.**

Taylor, J.A.

Journal of Sports Sciences (London)

ISSUE: 20 8 Aug 2002 607-613

**KEYWORDS:** Golf | Putting | Confidence | Visualization | Achievement | Skill | Comparison Study

The aim of this study was to determine the effects of positive and negative outcome imagery on golf-putting performance. Players of both high and low ability performed a golf-putting task in three imagery conditions:

- (a) a positive outcome imagery condition,
- (b) a negative outcome imagery condition and
- (c) a no-imagery control condition.

The task was conducted in a competitive setting, reducing the possibility of demand characteristics. We found that negative outcome imagery was detrimental to putting performance; however, performance in the positive outcome imagery condition was no better than performance in the control condition. There was also evidence to suggest that outcome imagery operated through the mechanism of confidence, as negative outcome imagery was detrimental to both confidence and performance. The results of the present study suggest that golfers should avoid visualizing negative images, as this could damage both confidence and performance.

ACH-3311

**The efficacy of video feedback for learning the golf swing**

Guadagnoli, M.  
Journal of Sports Sciences (London)

ISSUE: 20 8 Aug 2002 615-622

KEYWORDS: Golf | Swing | Visual Feedback | Videotape | Learning | Comparison Study

This study was designed to examine the efficacy of video instruction relative to that of verbal and self-guided instruction. Before training, 30 golfers were assigned at random to one of three groups: video, verbal or self guided instruction. Video instruction was defined as a practice session in which the teacher was aided by the use of video. Verbal instruction was defined as practising with the teacher providing verbal feedback.

Self-guided practice was defined as practising without the aid of a teacher. The participants had a pre-test, four 90 min practice sessions, an immediate post-test and a 2 week delayed post-test. During the pre-test and post-tests, all participants were required to strike 15 golf balls, with a 7-iron, from an artificial turf mat for distance and accuracy.

The results showed that all groups were equal on the pre-test. On the first post-test, the two instruction groups performed worse than the self-guided group. However, on the second post-test, the two instruction groups performed better than the self-guided group, with the video group performing best. We interpret these results to mean that video analysis is an effective means of practice, but that the positive effects may take some time to develop.

ACH-3312

**The vibrational mode structure of a golf ball**

Axe, J.D.  
Journal of Sports Sciences (London)

ISSUE: 20 8 Aug 2002 623-627

KEYWORDS: Golf | Ball | Impact | Acoustics | Vibration

In this paper, we report the discrete frequencies at which golf balls can vibrate, the mode patterns of these vibrations and how these modes can be excited. There are two broad classes of modes: those that radiate sound waves and those that do not. Both silent and acoustic modes are excited by tangential (i.e. spin-producing) impact forces; only acoustic modes are excited by radial impact forces. Exact analytical results for a homogeneous ball core are compared with finite element numerical results for both a core and a model two-piece ball. Correspondences are readily established for the important low-frequency modes, and the good agreement suggests the validity of these results for real golf balls. The results potentially provide the basis for a rapid, simple and non-destructive method of measuring the effective high-frequency elastic shear moduli of balls (and ball cores) as well as a method for 'tuning' the performance of balls for specific clubs. Some of these aspects are explored further in our companion paper in this issue.

ACH-3313

**On the acoustic signature of golf ball impact**

Shannon, K.  
Journal of Sports Sciences (London)

ISSUE: 20 8 Aug 2002 629-633

KEYWORDS: Golf | Ball | Acoustics | Impact

In this paper, we present results on the measurement and analysis of the sound that is produced by the sharp impact loading of a golf ball by a flat massive object (e.g. the face of a golf club). We discuss:

- (a) the motivation for such a study;
- (b) some necessary background information on how golf balls vibrate;
- (c) the techniques used to acquire and analyse the data; and
- (d) an analysis of the sound made by dropping balls on a smooth, massive concrete target surface. These results establish a simple method for rapid and non-destructive measurement of the effective high-frequency elastic shear moduli of balls and ball cores.

ACH-3314



**Development and use of one-dimensional models of a golf ball**

Cochran, A.J.  
Journal of Sports Sciences (London)

ISSUE: 20 8 Aug 2002 635-641

KEYWORDS: Golf | Ball | Theoretical Model | Impact

One-dimensional models of a golf ball are useful in modelling near-normal (90 degree) impact. The model described here has two masses connected by a non-linear spring in parallel with a non-linear damper. The behaviour of this system in collision with an infinite rigid mass is compared with the results of tests involving real golf balls.

Values of the four unknown constants are found by fitting the model results, over a range of impact speeds from zero to 50 m.s<sup>-1</sup>, to the coefficient of restitution and duration of contact found in the tests.

The simplest model (Model 1) was a good fit for duration of contact over the whole range of impact speeds, but for the coefficient of restitution only at high speed (above 20 m.s<sup>-1</sup>). However, when used with a similar model of a flexible faced club, the simple model predicted the coefficient of restitution of the club-ball combination, determined by direct testing, quite well and as such is a useful screening tool.

More complicated Models 2 and 3 fitted the rigid target coefficients of restitution better at low speed than Model 1. However, Models 2 and 3 have other disadvantages and are no better than Model 1 for high-speed impact with flexible faced clubs.

ACH-3315

**High-performance driver design: benefits for all golfers**

Hocknell, A.  
Journal of Sports Sciences (London)

ISSUE: 20 8 Aug 2002 643-649

KEYWORDS: Golf | Driver | Design | Impact | Achievement | Skill

Here I report experimental data to show the variation in impact efficiency between a driver and a standard golf ball with both impact speed and impact location.

The relationship of these data to the driver impact characteristics of the golfing population is presented as a key factor in the face design trade-off between increased driver performance and driver fatigue life. Based on these driver impact characteristics, a design principle is introduced that segments the golfing population based on driver loft, to deliver the benefit of increased impact efficiency to all golfers and particularly to average golfers.

Example drivers created using this design principle are then used to generate experimental evidence that counters the widely held belief that gains in impact efficiency offered by high-performance drivers benefit only those golfers capable of generating the highest speed impacts close to the face centre.

ACH-3316