Physiotherapeutic Assessment & Prevention of Overuse Injuries to the Lumbar Spine resulting in Intervertebral Disc and Facet Joint Pathologies in the Elite Male Golfer: An Evidence Based Guideline

Professional Assignment of

Amina Aly Naguib & Katie Jane Kersting
Hogeschool van Amsterdam
European School of Physiotherapy
Amsterdam, January 2008
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Acknowledgement

Behind every moment of work spent on this project lies an inspiration.

We had an idea, the idea quickly became a bunch of words scattered in illegible handwriting on a piece of notebook paper. The notebook paper became too small for the etchings and arrows placed upon it. Coffee stains covered some of the writing and the ink began to run. This is when a blank digital word document was created to organize the once scattered thoughts.

We would like to thank our families whom provided us with endless moral support and guidance from a far: we could have not gotten to where we are to date without you.

To our client, Ismail Naguib and colleagues at Golf in Egypt, we lend our warm thanks to you for sponsoring this work and for working in close contact with us through the past months.

We would like to address special thanks to our advisor and coach, Pim Ranzijn for his encouragement, advice and endless patience in improving our work.

I’d like to acknowledge Dr. Rida Azer, the person who first encouraged and introduced me to the field of physical medicine and gave me my first practical experiences (Amina).

To all the teaching staff, fellow students and friends in Amsterdam who helped get us through our years at HvA, We thank you.

Our once bland word document is now completed. The moments before swinging a golf club with precision and skill are congruent to this very moment as we acknowledge the people who helped us swing through our work. It is a moment filled with excitement, nervous twitches and finally a sense of calmness. No matter what path, distance or velocity the ball takes after follow through, we are filled with a sense of accomplishment.

We dedicate this paper to all the above whom have helped us grow, with skill and care.

Amina & Katie
DISCLAIMER

Every effort has been made to locate the most recent scientific evidence. Judgment is necessary when applying evidence in a clinical setting. It is important to note that weak evidence does not necessarily mean that a practice is unadvisable, but may reflect the insufficiency of evidence or the limitations of scientific investigation. This document is intended as a guide to practice. The ultimate decision of how to proceed rests with the clinician and the patient and depends on individual circumstances and beliefs (NHMRC, 1999).

Part III of this document was first published in January 2008 by Golf in Egypt, Cairo - Egypt. All responsibility for editorial matter rests with the creators of this guideline: Amina A. Naguib and Katie J. Kersting, prospective candidates for Physiotherapy BSc in the Hogeschool van Amsterdam (HvA). Any views or opinions expressed are therefore not necessarily those of HvA.

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Assessment & prevention of overuse injuries to the Lumbar spine resulting in intervertebral disc and facet joint pathologies in the Elite Male Golfer: An Evidence Based Guideline

This guideline provides an extensive evidence based approach to the assessment and prevention of low back pain in the professional golfer specifically dealing with chronic and overuse injuries to Lumbar intervertebral disc and facet joint pathologies. It follows an in depth review of international literature and professional consultations. To simplify clinical use and efficiency, this document is divided into three parts: Review of the evidence and The practical guideline, followed by an educational article: Golf & Physiotherapy: Preventing low back pain.
DOCUMENT OVERVIEW

GUIDELINE TEAM

Executive Committee

Amina Aly Naguib
Katie Jane Kersting

Professor-Coach: Pim Ranzijn

Review Committee

Cia P. Kesselaar
Bob van den Berg
I. EXECUTIVE SUMMARY

This document is the outcome of a unidisciplinary review of scientific evidence for the assessment and prevention of Low Back Pain (LBP) owing to overuse/chronic injuries in professional golfers. The Evidence is presented in Review format. The aim in conducting an evidence based review is to facilitate the integration of the best available evidence with clinical expertise and values and beliefs of patients.

This project was proposed by Golf in Egypt in conjunction with coordination by the Hogeschool van Amsterdam (HvA). The guideline development process was overseen by Pim Ranzijn along with a Dutch Board of Assessors in the HvA. Funding for the project was received from Golf in Egypt, a leading Egyptian Golf magazine. In return a secondary product of this guideline is to provide the magazine with a patient-friendly article delineating the prevention of LBP for Golfers.

The Review of the Evidence was conducted according to standards outlined by the Royal Dutch Society for Physical Therapy (KNGF) Development and implementation of Clinical Practice Guidelines in Physical Therapy and other referenced Guidelines and in accordance with ideas expressed by the pioneer of evidence-based medicine, Dr. Archie Cochrane (1977). Cochrane proposed the rationalization of interventions (diagnostic and therapeutic) to promote those with evidence of safety and effectiveness. To that end he suggested: promoting diagnostic tests likely to have a beneficial effect on prognosis, evaluating existing interventions to exclude those shown to be ineffective or dangerous, and determining the place of interventions when there is insufficient evidence of benefit.

Rational

Overuse, along with the asymmetrical nature of the golf swing may create habitual abnormal stresses on the lumbar spine, which might lead to injury and Low back pain. Low back pain associated with disc and facet joint pathologies caused by the repetitive nature of the Golf swing represent a significant health burden for professional male golfers.

Scope

This document provides information on the therapeutic assessment, diagnosis and prevention of LBP in elite male golfers. The primary focus is upon professional male golfers with intervertebral disc and facet joint injuries caused by overuse. The aim is to delineate the origin and anatomical structures involved with these pathologies via the best available diagnostic assessment tools and to finally focus on linking the complex nature of the golf swing with the resulting overuse pathologies.

- The document is concerned only with the management of chronic overuse injuries (over three months duration) associated with two specific pathologies in elite golfers: Intervertebral Disc and Facet joint pathologies in the Lumbar spine.
- Discussion of the management of general and non specific low back pain is beyond the scope of this document.
- No preexisting guidelines formed the basis for this document. A mono-disciplinary group undertook the work of drafting and finalizing the guideline.
- Where sufficient evidence has been available, recommendations have been made; however the aim of this work is to provide the non-specialized physiotherapist (PT) with information to guide decisions according to the evidence rather than being prescriptive.
- This master document containing the review of evidence serves as the source for summary publications for practicing physiotherapists and their patients, the idea being that same-source information
promotes partnership in decision-making and facilitates the provision of informed consent.

- This document is not intended to, nor should there be any implication that it would be used in a regulatory fashion to dictate practice.
- The evidence contained in this document is current to December 2007. Search dates are specified in each topic area.

Summary of Findings
The golf swing is a biomechanically complex motion, which if repeated over time, may result in low back pain. Low back pain is the leading complaint amongst professional golfers owing to the repetitive motion of the swing. Structural loading and motions of the spine during the golf swing lead to musculoskeletal dysfunctions, which in turn compromise the integrity of intervertebral discs and facet joints in the lumbar spine. Assessment of the lumbar spine is complex owing to the complexity of the anatomical structures involved. The reliability and validity of assessment tests are poor in nature and there is limited Evidence based research linking the golf swing with diagnostic tests of the lumbar spine. The available scientific literature suggests various exercise strategies to prevent golf related lower back injuries, namely, a detailed prescription of warm up, strength, flexibility and cardiovascular training.

Limitations of Findings
- There is both a lack of evidence (few or no studies conducted) and a lack of high quality, generalisable results in the area of golf specific physiotherapy assessment of the lumbar spine. The absence of evidence does not mean that an assessment tool is not effective.
- Few articles draw a distinct relationship between chronicity of injuries and the biomechanics of the golf swing
- Insufficient or conflicting evidence for an assessment tool does not mean there is no benefit. Clinical decisions should be made with knowledge of the existing evidence and consideration of patient-specific needs.

II. INTRODUCTION

This guideline is created for Physiotherapists treating elite level golfers presenting with Low Back Pain. It provides a guide for the physical therapy assessment and prevention of Low back Pain in the elite male golfer when the nature of the problem is specified and limited to patients with Lumbar disc and facet joint pathologies. It lends its self to physiotherapists whom are not golf-specific physiotherapists and whom know little of the biomechanics and nature of golf. This guideline follows the methodic physical therapeutic conduct in which it describes the diagnostic and prevention processes involved.

Objective of this guideline
The objective of this guideline is to describe the optimal physiotherapy assessment and prevention (effectiveness, efficiency and tailored prevention) for elite golfers diagnosed with low back pain associated with overuse injury resulting from the repetitive nature of the golf swing. All presented information is based upon current scientific, professional and social insights. The assessment will result in the correct diagnosis of lumbar disc and facet joint injuries, while the prevention will result in the ability to play a pain free game of golf regularly at the desired realistic level he is at, along with prevention of future chronic re-emergence of injury to the lower back.
Clinical question presentation

The following questions were targeted for answers by the creators of this guideline:

- What is the prevalence and etiology of golf related overuse injury to the lumbar spine?
- What is the magnitude of the problem?
- Golf Swing Biomechanics: what are the phases and anatomic postures during a golf swing?
- How do the postures taken during the golf swing compromise the low back?
- What anatomic features are most affected during the golf swing and how do their dysfunctions lead to the manifestation of discogenic and facet joint related pathologies caused by the repetitive execution of the golf swing?
- How are Disc and facet joint injuries defined?
- Which parts of the physical therapeutic diagnostic assessment are valid, reliable and useful in daily practice when treating professional golfers diagnosed with intervertebral disc and facet joint pathologies?
- What strategies are available, effective, and evidence based for the prevention of disc and facet joint injuries to the lumbar spine of golfers?

The mono-disciplinary working group

In 2007, a mono disciplinary working group was formed to answer the aforementioned clinical questions via relevant scientific literature and research. The findings are compiled into an evidence based guideline delineating the correct assessment tools and prevention plan for the use of physiotherapists. The work group is a professional group chosen by interest and or academic background in the area of common interest (Golf/low back injuries). All members of the working group have stated that they have no conflicting interests in relation to the development of this guideline. The development of this guideline took place between May 2007 and January 2008. This guideline has been developed according to the Development and Implementation of Clinical Practice Guidelines in Physical Therapy (Hendriks et al., 1996; Hendriks et al., 1998). The strategies used to gather literature and a review of the evidence is included with noted sources and the dates in which the searches were performed and accumulated. Recommendations for the therapeutic process are mostly based on scientific evidence yet when unavailable, recommendations were formed using consensus within the working group and professional advisors. The level of evidence is explained in more detail in the methods section of this paper and via the attached appendices (Criteria lists & Grading Outcome form).

Validation by the supported users

Upon finalization and publication of the final guideline, several physiotherapists (PTs) will be asked to put the product into use and grade it upon its clinical usefulness (graded on a VAS scale of 1-10). The PTs are chosen at random, the reason being that the target audience of this guideline is the practicing physiotherapist hence feedback from the prospective users of the guideline is effective. Due to time constraints and publishing/presentation dates, this is a future goal.
Constitution, products and implementation of the guideline

This guideline is made up of three parts: I. The Evidence. II. The practical guideline, and III. The article. Part II and III are the resultant products of part I. The guideline is implemented according to a standard of implementation strategies further described in the methodology section (Hendriks et al., 2000).

Use of this guideline

This guideline is a tool to be used in conjunction with a physician referral and diagnostic imaging of the injury site: Lumbar disc or Facet Joint pathology. The physiotherapist is to work in close contact with the referring physician so as to optimize benefits of this guideline.

III. ABOUT THIS GUIDELINE

The origin of golf related back pain stems from mechanical, discogenic, spondylogenic pathologies or facet joint degeneration (Armstrong, 1994; Hosea et al., 1994; Hosea & Gatt, 1996). The elite golfer on tour performs more than 2000 swings per week (Pink et al., 1993), hence repetitive strain on the musculoskeletal system increases the risk for an overuse injury to the spine.

Although there is much evidence based literature pertaining to golf injuries of the lower back, and likewise, assessment tests have been defined in the literature, there currently exists no fixed testing protocol for golf specific assessment of the injuries to the lumbar spine.

This review is the preliminary basis upon which the guideline for the assessment of discogenic (intervertebral discal changes) and facet joint pathologies to the lumbar spine in the top amateur and professional male golfer is based.

As much as possible, all information and recommendations presented for practical use in the guideline is based upon scientific evidence. Other than the scientific base of knowledge upon which the guideline is based, it takes into account recent professional developments and various factors such as practicality and efficiency.

It is worthy to note at this point that this guideline is to be used with patients whom have been diagnosed with specific low back pain (disc/ facet joint pathologies) and is therefore not to be used on patients whom have been diagnosed with non specific low back pain. The various forms of low back pain have been taken into account and based on the knowledge attained from articles and the various sources, the creators of this guideline have chosen to exclude those pathologies which are less prevalent amongst top amateur and professional golfers. Also worthy to note is that this guideline targets the general physical therapist who has a shallow base of knowledge about the sport of golf and its involved physical counterparts.

Impairments, disabilities and participation tribulations

The International Classification of Human Functioning, Disability and Health (ICIDH), internationally replaced by the ICF, present concepts and a framework of classification within rehabilitation professions to promote a uniform approach in the rehabilitation process. By Physical therapy standards, health problems are classified in terms of impairments, disabilities and participation problems. In terms of golf related chronic low back pain as a result of disc and facet joint pathologies due to golf swing biomechanics, impairments are classified as manifestations of a
disorder that involve body structure or physiological functioning, hence we label these as the anatomic structures involved: the lumbar spine (LS) and its counterparts: the discs and facet joints. Surfacing of these impairments occur as a result of primary impairments such as muscular imbalance, decreased carriability of structures, pain, sensory impairment or fear of movement (all of which will be further discussed later in this paper).

Disabilities prevalent in such cases are those which limit the patients’ ability to perform normal activities such as bending, stretching or walking. Due to the biomechanics of the golf swing, the body is under great pressure and forces, especially when the combination of flexion or extension with lateral bending and rotation of the spine occurs (an important property of the golf swing – to be discussed later). Finally, participation problems are the difficulties an individual experiences in his social life or work. Golf has been termed the “board room with green grass and blue skies”, it is not only a sport that is used recreationally but is also used as a form of “social business”. This combination of work and play is sometimes crucial to a patient’s daily life and if hindered by any means could cause him much social and work related handicapping.

Bio-psychosocial model
There is a clear underlying cause of the pathology in the patients this document is centered around. However, the bio-psychosocial model will not be forgotten due to patient specific reactions to their injury and ways of dealing with it. Even though disc and facet joint pathologies are not directly due to the interaction of biological, psychological and social factors, the later two can always have an affect on the biological manifestation of the injury and cannot be clearly separated.

Target Group
This guideline targets physical therapists from all educational and professional backgrounds. It targets those whom are faced with the assessment and prevention of the lumbar spine in the elite male right-handed golfer. This guideline does not require the therapist to have vast and in depth knowledge of golf swing biomechanics, instead it will simplify the steps at hand during the physical assessment. It however requires the therapist to have a solid base of understanding and implementation of the International Classification of Human Functioning, Disability and Health (ICIDH) framework. It is also crucial that the guideline user take into account the patient specific problem and look into treating the patient rather than the case itself. Knowledge of scientific findings will be presented, in essence the therapist will be capable of interpreting such data from evidence based research.

Cooperation with other Disciplines
To improve the effectiveness and efficiency of this guideline and the care provided, the physical therapist should be in close contact with the other health practitioners involved with each case. Primary care physicians, occupational therapists, psychologists, coaches, and athletic trainers involved in the specific case should come to an agreement and adopt a common policy in regard to their patient. Communication within and between the specializations is crucial to a full and efficient rehabilitation process.
PART I: THE EVIDENCE

I. INTRODUCTION & BACKGROUND

With an expanding market and a growing population of participants, Golf has become an increasingly popular sport, especially over the past decade (Batt, 1992; Carlow, 2006). In 1950, there were about 5,000 golf courses worldwide whereas to date there are over 15,000 golf courses with approximately 400-500 more added per annum. Likewise, the diverse population of golfers is also growing exponentially hence the amount of chronic injuries owing to overuse and swing biomechanics is a healthy amount. According to an estimate in the early 2000s, there are more than 55 million golfers around the world (Farraly et al., 2003). About fifty percent of golfers eventually suffer from golf-related injuries (Blanchard, 2007). Unlike many sports, golf is not limited to a certain age group, with the average golfer tending to be older than athletes in other sports (approximately 25% over the age of 65). Statistics show that high performance and skill are not limited by age and it comes as no surprise that golfers are more prone to injury, specifically overuse syndromes.

Even though they may have “better” swing mechanics and spend more time warming up prior to playing, professional golfers sustain more overuse injuries than amateurs (Carlow, 2006; Evans et al., 2005; Theriault & Lachance, 1998). This is a result of more lengthy time spent practicing and playing the sport (Carlow, 2006). Likewise, amateur golfers suffer from overuse injuries, however the result of their injuries are primarily due to poor mechanics, overzealous playing, or traumatic events on the golf course (Carlow, 2006; Theriault & Lachance, 1998).

The main causes of injuries to the elite golfer stem from overuse, technical errors during the swing, physical fitness deficiencies (aerobic, muscular strength/flexibility, postural instability & proprioception), no pre-game warm-up, carelessness towards other players or lack of etiquette, and natural environmental conditions (uneven course surface, wet grass, thunderstorm, etc.) (Theriault et al., 1996; McCarroll & Gioe, 1982; McCarroll et al., 1990; McCarroll, 1996). These causes may lead to muscular fatigue, muscular compensation and, ultimately, to injuries in both the amateur and professional golfer (Theriault & Lachance, 1998).

Injury to the lower back due to overuse is the most prevalent pathology in the elite level male golfer (Theriault & Lachance 1998). The golf swing involves a large range of motion and is repetitive, especially during practice. Combined with the large forces produced in the lower back, this may result in the increased risk of strains, disc herniation and facet arthropathy (Metz, 1999). The diagnosis of injury at each anatomical site has not been specifically examined in connection with golfers, even though the sites of injury have been discussed (i.e. Table I) in much scientific literature (Mallon & Hawkins, 1994).

The focus of this research is to link the main causes of injury to the lumbar spine in the professional male golfer (overuse and related physical dysfunctions of the musculoskeletal system) to the onset of Intervertebral disc and facet joint pathologies, and to locate the best physiotherapeutic assessment and prevention tools available while realizing their reliability and effectiveness.

Magnitude of the problem/ Epidemiology

Golf appears to carry a minimal risk of injury, however research studies tend to disagree, injuries do occur in professional as well as in amateur golfers (Gosheger et al., 2003; Theriault & Lachance, 1998; Duda, 1987; Theriault et al., 1996). Although they show similar overall anatomical
distribution of injuries by body segment, professional and amateur golfers present differences in the ranking of injury occurrence by anatomical site (McCarroll & Gioe, 1982; Hadden, 1991; Sugaya et al., 1999) (Table I). These differences are explained by individual playing habits, golf swing biomechanics (Theriault & Lachance, 1998). Professionals play about 6 to 10 hours per day on a daily basis, while amateurs play about 3 hours +/- 1.4 days per week (Theriault et al., 1996). McCarroll and Gioe (1982) found that repetitive practice swings were the most common cause of injury for men (64%) and women (75%). Furthermore, the professional golfer performs more than 2000 swings in one given week (Pink et al., 1993). This repetitive strain on the musculoskeletal system increases the risk of acquiring an injury.

Table I: Injury by Anatomical site distribution (4 cohort studies)

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amateurs</td>
<td>12 (1.3)</td>
<td>12 (1.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professionals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cervical</td>
<td>2 (3.3)</td>
<td>7 (3.5)</td>
<td>28 (3.1)</td>
<td>12 (3.0)</td>
</tr>
<tr>
<td>Spine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dorsal</td>
<td>13 (13.1)</td>
<td>30 (15.2)</td>
<td>244 (26.9)</td>
<td>8 (2.0)</td>
</tr>
<tr>
<td>Lumbar</td>
<td>35 (17.2)</td>
<td></td>
<td>93 (23.7)</td>
<td></td>
</tr>
<tr>
<td>Total spine</td>
<td>15 (24.6)</td>
<td>72 (36.4)</td>
<td>272 (30.0)</td>
<td>113 (28.7)</td>
</tr>
<tr>
<td>Upper limb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder</td>
<td>4 (6.6)</td>
<td>21 (10.6)</td>
<td>84 (9.3)</td>
<td>37 (9.4)</td>
</tr>
<tr>
<td>Elbow</td>
<td>8 (13.1)</td>
<td>38 (19.2)</td>
<td>234 (25.8)</td>
<td>26 (6.6)</td>
</tr>
<tr>
<td>Wrist</td>
<td>16 (26.2)</td>
<td>36 (18.2)</td>
<td>142 (15.6)</td>
<td>106 (27.0)</td>
</tr>
<tr>
<td>Hand</td>
<td>2 (3.3)</td>
<td></td>
<td></td>
<td>41 (10.4)</td>
</tr>
<tr>
<td>Total upper limb</td>
<td>30 (49.2)</td>
<td>95 (48.0)</td>
<td>460 (50.7)</td>
<td>211 (53.7)</td>
</tr>
<tr>
<td>Lower limb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip</td>
<td>8 (4.0)</td>
<td>22 (2.4)</td>
<td>9 (2.3)</td>
<td></td>
</tr>
<tr>
<td>Knee</td>
<td>4 (6.6)</td>
<td>8 (4.0)</td>
<td>66 (7.3)</td>
<td>26 (6.6)</td>
</tr>
<tr>
<td>Ankle</td>
<td>3 (4.9)</td>
<td>9 (4.6)</td>
<td>18 (2.0)</td>
<td>8 (2.0)</td>
</tr>
<tr>
<td>Foot</td>
<td>2 (3.3)</td>
<td>6 (3.0)</td>
<td>12 (1.3)</td>
<td>13 (3.3)</td>
</tr>
<tr>
<td>Total lower limb</td>
<td>9 (15.0)</td>
<td>31 (15.6)</td>
<td>118 (13.0)</td>
<td>56 (14.2)</td>
</tr>
<tr>
<td>Other</td>
<td>6 (9.8)</td>
<td>46 (5.1)</td>
<td>12 (3.0)</td>
<td></td>
</tr>
<tr>
<td>Cohort</td>
<td>61</td>
<td>198</td>
<td>908</td>
<td>393</td>
</tr>
</tbody>
</table>

McCarroll et al. (1990) found that players with a lower handicap (1-9) and aged above 50 years showed a higher prevalence of injuries and an 89% prevalence of injury amongst professional golfers at a rate of 1.74 per golfer. The higher injury rates, compared to non-elite golfers can be associated with the fact that they spend more time swinging and playing golf.

Table II: Prevalence of golf injuries among amateur and professional golfers (Theriault & Lachance, 1998)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Prevalence (%)</th>
<th>Injury rate per golfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professionals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>McCarroll &amp; Gioe</td>
<td>89</td>
<td>1.74</td>
</tr>
<tr>
<td>Amateurs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thériault et al.</td>
<td>25</td>
<td>1.31</td>
</tr>
<tr>
<td>McCarroll et al.</td>
<td>62</td>
<td>1.28</td>
</tr>
<tr>
<td>Batt</td>
<td>32</td>
<td>1.19</td>
</tr>
</tbody>
</table>
McCarroll and Gioe measured an average injury rate of close to 2 injuries per golfer and estimated the prevalence of injured golfers to be 88.5% from their survey of a cohort of 226 experienced (>15 years) professional golfers.

For professional golfers, low back pain is the most frequently reported musculoskeletal injury and is thought to result from the repetitive, asymmetrical nature of the golf swing and frequent play and practice (Gosheger et al., 2003; Sugaya et al., 1999). Factors that have been suggested to contribute to LBP in golfers include poor endurance and strength of the trunk muscles (Grimshaw et al., 2000; Horton et al., 2001; Pink et al., 1996; Vad et al., 2004; Weishaupt et al., 2000).

Prognostic factors

Depending on the amount of time spent playing Golf and at what level the patient plays (amateur or professional), different statistics prevail. 45% of amateurs and 54% of professionals complained of chronic ailments which prevented them from playing golf for an average of 5 weeks per year (McCarroll et al., 1996). Time lost from playing on the international golf tour as a result of injury averaged 9.3 weeks for men and 2.8 weeks for women (McCarroll et al., 1982). Time spent away from playing varied from one day to more than one and a half years. 10-33% of elite players will continue to play while still injured.

Patient characteristics

The motivation for the professional golfer to play golf is different than that of the amateur golfer even if they share equal interest and passion for the sport (Theriault & Lachance, 1998). The professional male golfer is playing the sport for a living on a daily basis for more cumulative hours than the amateur golfer, who may seek to gain health benefits, exercise and energy expenditure, relaxation, and sociability from contact with the natural environment (Theriault & Lachance, 1998). The patient specific goal and rehabilitation expectations of a professional golfer will hence differ than those of the amateur. Golfers over the age of 50 (senior golfers) account for about 25% of the total golfer population in the United States. They play 50% of all rounds of golf and account for 53% of all spending on golf (Tsai et al., 2005). This information shows us that the game of golf is not limited to one age group and is played by golfers of all ages. Professionals are susceptible to overuse injuries because of the time spent swinging. Even though they are used to the intensity and frequency of playing, this excessive play promotes overuse injury (McHardy et al., 2006). Because they depend on the game as a profession and not just a hobby, they continue on playing with injuries, resulting in chronic aggravation of an injury (McHardy et al., 2006).

Low back and Golf

Low back pain is the most common complaint among all golf related injuries (McCarroll, 1996; Horton et al., 2001). Furthermore, 90 % of all Professional Golf association (PGA) Tour injuries have been to the cervical and lumbar spine regions (Duda, 1987). On average, injuries to the low back cause the golfer to stop participating in his sport for 10 weeks (Gosheger et al., 2003). Not only is this a physical disability, for professional golfers earn their income by staying in the competitive game and do not get paid for standing on the sidelines caring for their unfortunate injuries. Such problems can cause there to be a link between the psychological and physical manifestation of the injury and its rehabilitation course.

Swinging a golf club and playing elite level golf involves the spine to function repetitively to a great extent. The spine is involved with the transmission of forces and the coordination of activities between the upper and lower extremities. Due to the mechanics of the swing, the low back is
subject to large ranges of motion and forces: downward compression, side to side bending, sliding, back to front shearing (Lett, 2000; Hosea et al., 1990).

![Figure I: Forces acting upon the lumbar spine](adapted from www.spsclinics.co.uk/hometruths/backschool/)

Forces applied to the dorsolumbar spinal area during the golf swing act in four directions: compression, anteroposterior traction, rotation, and lateral flexion (Figure II). These four multidirectional forces are substantial during the golf swing and create damage to the lower spinal components (paraspinal muscles, intervertebral discs, vertebral ligaments, facetar joints and the posterior arc (spondylolysis) (McHardy et al., 2006).

II. BIOMECHANICS & KINEMATICS OF THE GOLF SWING

Golf swing Biomechanics: why the knowledge is needed

McHardy & Pollard (2005) defined the golf swing as the process of swinging the club to hit the ball. The swing represents the phase in which there is the greatest demand, from a biomechanical perspective, on all of the involved musculoskeletal structures (Theriault & Lachance, 1998).

At first glance, the golf swing appears rather quick and simple. When analyzing the various technical aspects of the swing, one will discover that it is much more complicated than it seems. Due to its’ dynamic nature of movement, the golf swing has the potential to cause injury to the golfer (McHardy & Pollard, 2005). When an elite golfer performs his golf swing numerous times per day, week and month, the potential for an overuse injury is heightened and may lead him to acquire a chronic injury. Different injuries occur in different parts of the swing and frequently involve soft tissue injuries (Gosheger et al., 2003; McCarroll et al., 1990; Batt, 1992, McCarroll & Gioe, 1982). Since injury is more likely to occur during the swing to hit the ball (Theriault & Lachance, 1998), it is important for the treating physiotherapist to have an understanding of the mechanics of the golf swing. This solid base of knowledge will help in the understanding of the etiology of the injury and hence improve its management (McHardy & Pollard, 2005). Golf biomechanics applies the principles and techniques of mechanics to the structure and function of the golfer with the aim of improvement of golf technique and performance (McHardy & Pollard, 2005). Farrally et al. summarized research findings in golf and stressed the importance of the application of sound biomechanics to improve golf performance.

Exertion of the trunk and upper extremities in golf (and other such sports), low back injuries are common (Farfan, 1996). Intrinsic and extrinsic factors are involved in the swing; they affect the golfer’s ability to hit the ball with power and accuracy. If the swing is not free flowing and efficient, injuries are likely to occur (McHardy et al., 2006).
Stages & Phases of the Golf Swing

A golfer will use a driver (wood or long iron) to hit the ball as far as possible while still guaranteeing the ball landing on the fairway (Hume et al. 2005). Through time, there has been a variety of classification schemes used to describe the phases of the golf swing (Hume et al., 2005). For the use of this document, the golf swing is divided into seven stages other than the Address position (set-up) (McHardy & Pollard, 2005): The early backswing (BS), late backswing (BS), top of swing, downswing, impact, early follow-through, and late follow-through. The swing is also divided into four phases: the address, backswing, downswing “acceleration”, & follow-through (McHardy & Pollard, 2005; Hume et al., 2005). For the purpose of this document, descriptions of the stages and phases are defined in the tables and pictorial representations below (Table III, Table IV, Figure II).

![Figure II: Pictorial representation of the stages of the Golf Swing](http://www.golfdigest.com/instruction/swing/2007/11/photos_els)
Table III: Description of Stages during the Golf Swing (Hume et al., 2005; McHardy et al., 2006)

<table>
<thead>
<tr>
<th>STAGE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address (Set-up)</td>
<td>Position of body just prior to initiating the golf swing: Feet are shoulder or hip width apart, knees slightly flexed (20-25 °), trunk flexed (45 °) at the hips, posterior pelvic tilt, arms relaxed hanging down from shoulders, right shoulder slightly elevated(right lateral shoulder tilt 16 ° (result of right lateral bending in the spine and slight depression and downward rotation of right arm and scapula – right hand is lower on the club than left hand), hands and wrists are activated gripping onto the club. 50-60% of golfer’s weight is on the back foot.</td>
</tr>
<tr>
<td>The early backswing (BS),</td>
<td>The body begins to move, rotating the trunk and arm upwards away from the target, purpose being to position golfer’s GOC and club head so as to execute a correct &amp; powerful downswing, to stretch the musculature and joint structures responsible for generating power in the downswing. Shoulders rotate and pull hips into a rotated position while the arms move upward.</td>
</tr>
<tr>
<td>Late Back Swing (BS)</td>
<td>Rotation continues, bringing the club further away from the starting position.</td>
</tr>
<tr>
<td>Top of Swing (Top)</td>
<td>Transition point from back to downswing: elbows are level, shoulders turned two times as much as the hips and hands are away from the body. Right arm is abducted (75-90 °) and externally rotated (90 °). Left elbow is extended, left shoulder is internally rotated and horizontally adducted across the chest. Left scapula is abducted, elevated and outwardly rotated, and the wrist and hands are cocked. The left posterior rotator cuff muscles are stretched and the GH joint is in an impingement position. Left leg bears about 40% of the bodyweight and is passively externally rotated because of the right pelvic rotation. If patient has limited hip external rotation or tibia internal rotation, the heel leaves the ground (may cause stress on the left leg). If the patient has limited hip internal rotation, the feet can be abducted 10-20 ° in compensation.</td>
</tr>
<tr>
<td>Downswing (DS)</td>
<td>With little leg movement, the arms begin to drop down (release) while the elbows are still level in the first half of this stage. Purpose of the DS is to bring the club head to the ball in the correct plane with maximum velocity (on average it takes an elite golfer 0.23 seconds to perform this). Left pelvic rotation (begins before arms have completed the backswing) The left arm externally rotates and moves toward the midline, the right arm internally rotates and adducts and the elbow extends.</td>
</tr>
<tr>
<td>Impact</td>
<td>Once again, the club, shaft and hands are in line with the player’s belt buckle. This is a mirroring of the address stage in which the spine and back of the head are aligned. Likewise, the shaft angle is the same as at address (club face points in the same direction as the back of the left hand at the target. Shoulder rotation is about 27 ° and hip rotation about 43 ° to the left.</td>
</tr>
<tr>
<td>Early follow-through</td>
<td>Extension of down swing and impact positions. The club and trunk rotate towards the target. The arms swing past the left leg (front leg for right handed players), as club is swung through the ball and up to the top, Deceleration of the body and club head by using eccentric muscle activity. Hands and wrists follow the plane of the swing path. Left shoulder and arm further abduct and externally rotate, right shoulder and arm adduct and internally rotate.</td>
</tr>
<tr>
<td>Late Follow-through</td>
<td>When the golfer’s hands reach the shoulder level and both elbows flex to slow down the arm and trunk rotation speed while keeping postural stability. Trunk and hip rotation continues to the left, left leg internally rotates (weight absorbing), left ankle supinates. Golfer finishes in a balanced position with the trunk facing the target in slight hyperextension and lateral flexion. Hands behind left ear and head rotated to the left.</td>
</tr>
</tbody>
</table>
## Table IV: Phase description during the Golf Swing

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Address (starting position/ preswing posture)</strong></td>
<td>Equal weight distribution on both feet (shoulder width apart), slight anterior flexion of the trunk at the hips (keeping the shoulders, knees and feet aligned vertically in the side view), keeping the back straight to permit easy rotation, and an extended relaxed arm position while avoiding a straight overextended, tense arm posture</td>
</tr>
<tr>
<td><strong>Backswing (From Address to top)</strong></td>
<td>Weight shift to the right foot (for a right handed golfer) while keeping the vertebral column perpendicular to the ground in the frontal plane (upper body of the player remains leaning forward towards the ball). At the same time, rotation to the right side around the spinal vertical axis of the knees, hips and upper limbs is taken. This raises the club to its highest point in order to obtain the widest possible arc of motion</td>
</tr>
<tr>
<td><strong>Downswing &amp; ball impact (from top to impact “Acceleration”)</strong></td>
<td>Activation of an anatomical multi-lever system gives the club a downswing in a rotational, angular trajectory and maximum speed which will determine the distance covered by the ball. These levers are activated in order from the ground level upwards; from the feet to the wrists. Weight shift to the left foot created by a linear and parallel movement of the hips and shoulders of the same side and by keeping the spine in a position perpendicular to the ground. At the same time the knees, hips and trunk start to rotate to the left side. Left-sided uncoiling is made possible because of the strong muscular activity of the abdominal muscles which act as trunk rotators (about 3 times the strength exerted during the backswing by the external oblique muscles) Uncoiling is possible by the paraspinal (erector spinae) muscles acting as spinal stabilizers (about 4-5 times the strength exerted during the backswing by the paraspinal muscles) and the right shoulder adductors and internal rotators (about 3-4 times and 6-7 times, respectively, the strength exerted during the backswing by the right subscapular and major pectoralis muscles). The combined effect of these actions is to bring the arms down in acceleration just prior to the ball impact. IMPACT Wrist and hands complete the acceleration of the club at ball impact by providing the ultimate push of the club head. The action is like a whip as the right hand gradually pronates during the hitting. The compressive force on the left leg and particularly on the left hip, exerted from weight transfer to the left side becomes significant (torque force of up to 300-400 pounds/inch: 8.8-11.7 kg/m²).</td>
</tr>
<tr>
<td><strong>Follow-through (from impact to end)</strong></td>
<td>Progressive deceleration of the club and by the rotation of the body towards the left around the axis of the spine. Superimposed and parallel left rotatory motion of both the hips and shoulders; a movement which ends when the body faces the target. Muscular activity is predominantly that of the muscles of the spine and the shoulders: - Rotator cuff muscles: supraspinatus, infraspinatus and subscapularis - Supra &amp; infraspinatus on the left side are activated mainly during follow through, while the subscapularis remains active to a similar extent to that during the forward swing and ball impact. The abdominal, dorsal, pectoral and anterior portion of the deltoid muscles are also implicated.</td>
</tr>
</tbody>
</table>
Trunk Dynamics and motion

Evolution of the Golf Swing & the X factor

The golf swing has evolved over the past 50 years, allowing the golfer to take advantage of evolution of equipment and understanding of the golf swing (Hosea & Gatt, 1996). The classic swing differs from the modern swing in that the spine is coiled in such a fashion for the purpose of power generation and striking distance of the ball. This is important when considering the effects on the lower back/spine and prevalence of overuse injuries to the lumbar spine. The golf swing consists of trunk rotations about three anatomical axes. The modern golf swing promotes a large shoulder turn and less parallel shoulder/hip turn about these axes. During the backswing, the upper torso rotates against restricted pelvic rotation to produce maximum angular displacement between the shoulders and hips (McLean, 1997).

Figure III: Classic & Modern Swing Examples
a) Steve Ballesteros, 1984 (Classic swing) b) Sergio Garcia, 135th Open Championship, 2006 (Modern swing)

In the modern swing, the pelvic movement is restricted while the shoulder is turned during the backswing. This is done to promote the storing of power (elastic energy) and hence creating the maximum club head acceleration at impact, leading to the build-up of greater torque in the back and shoulders that in turn leads to greater angular displacement which creates a greater angular club head speed/velocity in the downswing (Colby, 1999). The follow-through is characterized by a hyperextension of the back, in the reverse “C” position (Hosea & Gatt, 1996). As aforementioned, the maximum difference in rotation of the hips and shoulders at the top of the backswing is called the “X-Factor” (Hume et al., 2005; McLean, 1997). Golfers using the modern swing have a larger x-factor, this means that the muscles of the lower, mid-section and upper body are quickly stretched before they shorten. The effective use of such golf swing strategy enables the golfer to hit the ball to greater distances. Professional golfers generally use a longer backswing amplitude (greater angular displacement) in less time than amateur golfers, increasing the velocity of the backswing and hence the rate of stretch (Cochran, 1968; McTeigue et al., 1994). McLean (1997) showed that the greater the X-factor, the higher a professional golfer was ranked on the driving distance. This larger x-factor trend during a golf swing might not be all good due to the fact that twisting may be associated with the development of back pain (Farfan et al., 1970). The trunk rotation primarily occurs in the thoracic spine (White & Panjabi, 1978; Pearcy et al., 1984). When the shoulders and
thoracic spine rotate against the lumbar vertebrae, compression, shear and torsional stress may increase especially near the junction of the middle and lower back (Armstrong, 1994). If a golfer attempts to generate a maximum hip to shoulder angular displacement, beyond his physical trunk rotation limits, the excessive rotational moment on the spine may not be absorbed properly by the lumbar spine and can, over time, stress the soft tissue of the lumbar region (Lindsay & Horton, 2002). In a study done on golfers with and without LBP, the maximum X-factors measured were similar but golfers with LBP had less trunk rotational flexibility and as such the trunk rotation in their swings went beyond their physical limits (Lindsay & Horton, 2002).

Table V: X-factor and golf performance (Hume et al., 1996).

<table>
<thead>
<tr>
<th>Study</th>
<th>Subjects (PGA golfers playing off scratch or better)</th>
<th>X-factor</th>
<th>X factor stretch</th>
<th>Performance variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burden et al.</td>
<td>8 amateur male handicap = 7</td>
<td>70 +/- 20°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceetham et al</td>
<td>1. 10 male PGA</td>
<td>11% greater in PGA than in amateurs</td>
<td>19% greater in PGA than in amateur</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. 9 male amateurs handicap = 15</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| McLean         | 1. 5 PGA long hitters                                | 1. 38°   | 2. 24°          | Average ranking for driving distance on PGA tour:
|                | 2. 5PGA short hitter                                 |          |                 | 1. 19 2. 2.161                         |
| Mcetigue et al.| 1. 51 male PGA                                       | 1. 32°   | 2. 29°          | Downswing times:
|                | 2. 46 male senior PGA                                |          |                 | 1. 1.09 sec 2. 1.03 sec 3. 1.28 sec   |
|                | 3. 34 amateur males handicap = 17.5                 |          |                 |                                       |

PGA = professional golf association

*All results are mean ± standard deviation (where reported)*

Forces and spinal loading during the golf swing

During the golf swing, the forces applied to the lumbar spine act in four directions: compression, shear, lateral flexion, and torsion (Hosea et al., 1990). In a study done by Hosea et al. in 1991, they found that both amateur and professional golfers develop similar peak compression loads of over 8 times body weight, while the professional golfer was reported to attain lower levels of three other forces (shear, lateral flexion and torsion), due to better technique. In another study done on 61 human cadavers Adam and Hutton (1998) did single load tests of the spine: Combining lateral and forward flexion to the elastic limit of the supra/intraspinous ligament, and compressing it by a force rising at 3000 Newton/second (N/sec) up to a predetermined maximum load corresponding to the back muscle activity for a person of the same age and body mass as the cadaver undergoing testing. 5448 Newton (N) was the average compression force needed to cause sudden prolapse (ranging between 2760N-12968N). This was in the range of the forces developed when swinging a golf club according to the aforementioned study by Hosea et al in 1990. Hosea et al. suggest that the rate at which the spine is stressed during the swing serves as a protective mechanism for the discs (Hosea et al., 1994). Another protective mechanism for the spine has been suggested to come from the trunk muscles (Bartelink, 1957; Morris et al., 1961).

Spinal Rotation, lateral flexion, velocity and spinal loads
The fast rotation velocity of the spine during the golf swing is a risk factor for injuries to the low back (Hosea et al., 1990). The speed of the club head before hitting the ball can reach 160 km/h attained in 0.2 seconds (Stover et al., 1976). Given the statistics, a ball is hit repeatedly an average of 50 times during an 18-hole course, or 300 times or more during a practice session by a professional, it is not difficult to deduce that injuries can occur either through overuse or through actions causing severe trauma (Theriault & Lachance, 1998).

The increased forces on the lumbar spine from the golf swing are detrimental to the golfer’s health and physique, however the difference between the rotational velocities of specifically the lumbar spine between professional and amateur players is unknown to date. Lindsay and Horton (2002) measured the total trunk rotational velocities between golfers with and without LBP. The results were not significant since the velocities of the pain free group were not slower than the LBP group (most of the spinal rotation occurred via the thoracic spine). Since the low back injuries in golfers are thought to be caused by the forces that are associated with the lumbar movements, there is a need to research the lumbar spinal rotation velocities alone, separated from the entire trunk.

As a means to amplify the speed of the club head, rather than the proper mechanics of rotating the pelvis, golfers use too much lateral weight shift of the lower body at the top of the backswing, (Geisler, 2001). When the lower body is shifted to one side, the spine bends laterally to the other side in order to keep the balance (figure III). This compensatory movement will result in difficulty for golfers to keep the anterior tilt angle of the spine that they had at address position (Geisler, 2001). The golfer using this swing pattern is forced into reverse trunk inclination in the early downswing period by sliding the hips back laterally toward the target in order to hit the ball. This chain reaction forces the spine to simultaneously bend laterally to the right in order to reestablish the original spine and torso inclination. When this violent loss and reestablishment of the spine angle takes place, the spine undergoes significant rotation and shear forces (Geisler, 2001). This potential injury mechanism may be able to explain why golfers who demonstrated greater left side bending on the backswing had LBP resulting from the golf swing (Lindsay & Horton, 2002). Lindsay and Horton showed that the maximum trunk extension angles during the golf swing in golfers with LBP were less than that of the golfers without LBP. This may be a protective mechanism taken by injured golfers to prevent back pain since they were tested with existing pain.

Figure IV: Lateral weight shift of the lower body, hips slide back laterally toward the target
Trunk muscle activity during the golf swing

In a study by Pink et al. (1993) muscle firing patterns in the trunk (bilateral erector spinae and abdominal obliques) were analyzed during the golf swing. Findings showed that the abdominal muscles contract for trunk flexion and rotation, while back musculature may mainly contract for trunk stabilization (control trunk movements, transmit power coming from the hips, and slow the body down after impact). Their results demonstrated low activity in all muscles (<30% of maximum voluntary contraction (MVC)) during the initial takeaway phase, and high and constant muscle activity in all muscles (>30% MVC) during the forward swing to early follow through. According to their findings, Pink et al. recommended that a strengthening program be implemented for trunk muscles to prevent injury from overuse and incorrect biomechanics. Like Pink et al., Watkins et al. noticed the same observations plus very active gluteal muscles during the forward swing and acceleration phase (Watkins et al., 1996).

In the study by Hosea et al., trunk muscle activity and spinal loads during the golf swing on the professional and amateur golfers were investigated (bilateral erector spinae, rectus abdominis, and external oblique) (Hosea et al., 1990). Overall, the muscles on the left side of the trunk were responsible for the initial twisting of the trunk from address to the top of the backswing. These muscles cause lumbar axial torque to the right during the backswing phase. The muscles on the right side of the trunk play a major role during the downswing and created axial torque to the left. During the downswing, maximal activities of all trunk muscles occurred (especially those on the right side), corresponding to the maximum spinal loading of the anterior-posterior shear force, lateral shear force, and axial torque. Back muscles contracted symmetrically during this time for spinal stabilization and compression force generation.

Different musculature and joints are involved in each of the phases associated with the golf swing. Their main function is to create a multi-lever system that generates maximal speed to hit the golf ball at maximal acceleration.

Table VI: Injuries Associated with the Spine at Each Phase (Theriault & Lachance, 1998)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Injury</th>
</tr>
</thead>
</table>
| From Address to end of Backswing           | Upper body anterior flexion at dorso-lumbar spine instead of at hips increases risk of hypermobility of vertebra and abnormal muscular tension during the backswing.  
- Too wide a stance increases the tension on the spine and reduces the ease of trunk rotation  
- An overly long backswing may cause a rotational trunk injury or may throw the player off balance leading to ground impact injuries.  
- Leftward spinal tilt, instead of being perpendicular to the ground, during the rightward shift increases the chance of an opposite spinal curve (reverse C) posture at the end of the follow through. |
| From Forward swing and acceleration to impact | Thoracic and abdominal muscular strains can occur after vigorous trunk rotation on the downswing |
| From Early Follow through to late follow through | Injury to the hips or dorsolumbar spine can occur if the deceleration of the follow through is too brisk/aggressive.  
- An overly powerful drive, including a reversed “C” lordotic spinal curvature, can induce abnormally high stresses on the dorsolumbar vertebral bodies, especially on the posterior joint |
III. CAUSES OF GOLF RELATED INJURY OF THE LOW BACK

Golf related back pain stems from mechanical, discogenic, spondylogenic pathologies or facet joint degeneration (Armstrong, 1994; Hosea et al., 1994; Hosea & Gatt, 1996). The elite golfer on tour performs more than 2000 swings per week (Pink et al. 1993) hence repetitive strain on the musculoskeletal system in professional male golfers increases the risk for an overuse injury to the spine. In short, the causes of golf injuries to the low back are primarily: overuse, technical errors, physical constraints (aerobic, muscular strength/flexibility – trunk & hip, back proprioception, postural stability), lack of warm up, and natural environment (uneven surfaces, wet conditions) (Gosheger et al., 2003; Theriault & Lachance, 1998). The interest of this paper focuses on the overuse injuries to the lumbar spine in elite male golfers due to its reported prevalence (see table below).

TABLE VII: Main specific causes reported for golf injuries amongst amateur & professional golfers in 2 studies (Theriault & Lachance, 1998).

<table>
<thead>
<tr>
<th>Reference</th>
<th>Overuse</th>
<th>Technical errors/ deficiencies</th>
<th>No pre-game warm up</th>
<th>Hit by a ball or club</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professionals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>McCarroll, 1996</td>
<td>270 (79.9)</td>
<td>58 (17.2)</td>
<td>-</td>
<td>3 (0.01)</td>
<td>7 (0.02)</td>
</tr>
<tr>
<td>Amateurs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theriault et al., 1996</td>
<td>24 (20.0)</td>
<td>95 (77.0)</td>
<td>-</td>
<td>-</td>
<td>2 (3.0)</td>
</tr>
<tr>
<td>McCarroll, 1996</td>
<td>204 (28.9)</td>
<td>454 (62.7)</td>
<td>60 (8.3)</td>
<td>36 (5.0)</td>
<td>50 (0.06)</td>
</tr>
</tbody>
</table>

(a) The various studies presented in this table show that overuse and technical errors during the swing are the leading causes of golf injuries. (b) The table demonstrates that recreational golfers injure themselves more often because of technical deficiencies while professional golfers sustain injuries due to overuse.

Cause & effect : The links

This guideline assumes that the elite golfer at hand has a biomechanically sound swing and that overuse is the main issue at hand. Over-ruling technical errors in the professional leaves us with Deficiencies other than trunk dynamics, which add to the link between swing dynamics and injuries to the low back.

Overuse

Per the table above, it is shown that professional golfers sustain injuries due to overuse (79.9%) (Theriault & Lachance, 1998). More lengthy time practicing and playing is typical of any professional top sporter. The habits of professional golfers are playing almost every day, between 6-10 hours per day to maintain or improve the quality of their game (Theriault & Lachance, 1998). In contrast, the amateur plays an average of 3.0 +/- 1.4 days and 14.7 +/- 7.7 hours per week (Theriault & Lachance, 1998). Due to the mechanics, forces placed on the spine, and complexity of the golf swing, the low back is subject to large ranges of motions and forces (McHardy et al., 2006), and the amount of time a professional golfer spends swinging places him at more risk for LBP and injury to the Lumbar spine. Other than dynamics of the trunk, factors such as aerobic deficiency, muscular imbalance (strength/flexibility), proprioception, and postural instability contribute to the relationship between the golf swing biomechanics and low back injuries.
The links:

Aerobic Deficiencies/ Cardiorespiratory Fitness

“Fatigue in the later rounds of golf is as common as broken tees” (Yocum, 1999)

It is suggested that one of the crucial factors in determining the outcome of a round of golf is the cardiorespiratory fitness level of a golfer (Russel & Owies, 2000). A lack of cardiovascular endurance leads to increased levels of fatigue which leads to a loss of concentration, which hence affects the shot making ability of golfers (Russel & Oweis, 2000; Wilmore & Costill, 1994). Fatigue influences factors such as strength, speed, reaction, concentration and neuromuscular coordination (Wilmore & Costill, 1994). In golf, where high skill level is combined with a small margin for error, the smallest sign of fatigue can greatly affect performance.

Flexibility

Appropriate flexibility of trunk and hip muscles is suggested to decrease risks of Low Back injuries in golfers (Lindsay & Horton, 2002; Vad et al., 2004). Appropriate flexibility can decrease the resistance in the various tissues in the trunk and hip muscles and prevent the changes of normal lumbar curve caused by tight muscles. A golfer with good flexibility is less likely to injure his lumbar spine by exceeding tissue stretchability during the golf swing. More flexibility may decrease the forces applied to the lumbar spine. In order to prevent low back injuries in golfers with LBP, flexibility must be assessed.

Strength

Strength is defined as the maximum ability to apply or resist force (Wilmore & Costill, 1988). In golf, a player needs both strength and power (product of strength and speed: force multiplied by velocity). We can deduce that muscular endurance is important along with this concept due to its definition: the ability of the muscle to repeatedly develop near maximal force. Strengthening the muscles involved in the golf swing is important to reduce the chance of injury and play a better game.

Strengthening the muscles that support the spine is usually used as a preventative and treatment modality for patients with and without LBP (Gundewall et al., 1993). Whether or not trunk muscle weakness contributes to the incidence of LBP is controversial and needs to be further looked into (Newton et al., 1993). Some studies showed a negative correlation between trunk muscle strength and incidence of LBP (Biering-Sorensen endurance test), but it has been shown that weak trunk musculature is one of the strongest risk factors for a first time experience of LBP (Latimer et al., 1999). Since golfers need a high powered trunk rotation, it is indicated that research be done on golfers with and without low back pain in relation to the trunk rotation strength.

Hip muscles are responsible for pelvic stability and force transmission between the lower extremities and the trunk (Lee, 1999). Imbalances in trunk and hip muscle strength may be a factor causing LBP (McNeill et al., 1980). In athletes, the imbalance in strength between muscle groups can be caused by increases in the strength of muscles acting in opposite direction where as in non athletes, this imbalance may be caused by weakness in one of the muscle groups (Andersson et al., 1988).
Proprioception and Postural Stability

Literature shows that patients with LBP demonstrate difficulty in positioning and repositioning the lumbar spine or when placed in a position in the middle of the lumbar ROM (Newcomer et al., 2000). Mechanoreceptors responsible for proprioceptive input have been found in various connective tissues, facet joints, and discs (McLain & Pickar, 1998; Menage et al., 1995). Damage to even the slightest area on a facet joint may denervate the facet and this in turn may have an affect on the long term function of the spinal joint (McLain & Pickar, 1998). It is important to have good proprioception for coordination of muscles and collective movements, especially when dealing with complex movements such as the golf swing for any problems in balance and coordination could alter the swing pattern of the golfer and cause extra stress to the lumbar spine.

Postural stability and balance requires coordination of many systems and muscular imbalances, or impairments can hinder postural stability (Luoto et al., 1998). This is crucial when dealing with golfers with low back pain for if the integrity of their muscles is off, or if their balance is at stake, this may not only challenge the efficiency and accuracy of their swing, but also increases their chances of getting injured.

IV. SPINE ANATOMY IN RELATION TO THE GOLF SWING

Spinal Motion

The spinal column functions primarily to provide stability and posture, to allow mobility of the head, neck and trunk in space, to support and transmit loads from the upper body to the pelvis, to absorb shock, and to protect the spinal cord. The lumbar spine furnishes support for the upper body and transmits the weight of the upper body to the pelvis and lower limbs. Due to the strategic location of the lumbar spine, this structure should be included in any examination of a golfer with LBP.

For correct posture one needs a spine angel of lumbar 40°, thoracic 35° and sacral 45°. If these change, the total center of gravity (COG) changes. When the COG is out of place, the spine tries to regain balance and compensations occur (e.g. scoliosis or lordosis). Movements and biomechanics can be permanently altered if this occurs. As explained earlier, the golf swing requires the basic movements of the spine (flexion, extension, lateral flexion and rotation) sometimes to a greater extent than is normally used in activities of daily living.

![Figure V: Spinal Anatomy](http://www.nationalpainfoundation.org/MyTreatment/articles/images/BackAndNeck_Spine.jpg)
Intervertebral disc & facet joint anatomy relative to the golf swing

The complex of facet joints and intervertebral discs is referred to as the Motion segment. With a normal intact disc, the facet joints carry about 20% to 25% of axial load, with degeneration of the disc; this may reach up to 70%. The disc also provides 40% of torsional and shear strength. Right handed golfers exhibit a higher rate of right side osteophyte formation on x-ray (p<0.01) as well as right-sided facet joint degenerative changes on computer tomography (CT) (p<0.01) (Sugaya et al., 1999). During the golf swing, the lateral bending angle and axial rotation velocity play a role in lumbar degeneration injuries (Sugaya et al., 1999). The key role played by the intervertebral disc is cushioning and allowing angular trunk rotation (Adams, 1993; Hosea et al, 1996). Any disc degeneration, especially in older golfers, will limit the power of the swing, and in turn make other spinal components more vulnerable to injury and in turn create chronic discomfort amongst these players (Theriault & Lachance, 1998).

Intervertebral Disc Anatomy

The intervertebral discs make up approximately 20% of the total length of the vertebral column. The unique functions of the intervertebral disc are shock absorption (distributing and absorber), hold the vertebral together, allow movement between the bones, separate the vertebra as part of a functional segmental unit acting in concert with the facet joints and by separating the vertebrae, to allow the free passage of the nerve roots out from the spinal cord through the intervertebral foramina. With increasing age and strenuous repetitive movements the height of discs decreases, as a result of disc degeneration and loss of hydrophilic action in the disc. Pain sensitive structures around the intervertebral disc are the anterior and posterior longitudinal ligaments, vertebral body, nerve root, and cartilage of the facet joints.

With movement of fluid vertically through the endplate the pressure on the disc is decreased as the patient assume the natural lordotic posture in the lumber spine. The direct vertical pressure on the disc can cause the disc to push fluid into the vertebral body. If pressure is great enough, defects may occur in the endplate, resulting in Schmorl’s nodules (herniations of the nucleus into the vertebral body).

Table VIII: Activity and percentage increase in disc pressure in disc pressure at L3
(Modified from Magee, 2002)

<table>
<thead>
<tr>
<th>Activity</th>
<th>%</th>
<th>Activity related to golf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>15%</td>
<td>over the course of the 18 holes</td>
</tr>
<tr>
<td>Side bending</td>
<td>25%</td>
<td>during swing</td>
</tr>
<tr>
<td>Small jumps</td>
<td>40%</td>
<td>when they win/ score a hole in one</td>
</tr>
<tr>
<td>Bending forward</td>
<td>150%</td>
<td>Swing</td>
</tr>
<tr>
<td>Rotation</td>
<td>20%</td>
<td>Swing</td>
</tr>
<tr>
<td>Lifting a 20-kg weight with</td>
<td>73%</td>
<td>picking up golf bag</td>
</tr>
<tr>
<td>The back straight and knees bent:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifting a 20-kg weight with</td>
<td>169%</td>
<td>picking up a ball, placing a ball</td>
</tr>
<tr>
<td>The back bent and knees straight:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Facet Joint Anatomy

The lumber spine consists of 5 pairs of facet joints, also called apophyseal or zygoapophyseal joints. These diarthrodial joints consist of superior and inferior facets and a capsule. The facets are located on the vertebral arches. The superior facets or articular process face medial and backward and in general, are concave. The inferior facets on the other hand face lateral - forward and are convex. The function of the posterior facet joint is to direct the movement that occur in the lumber spine. Due to the shape of the facets rotation is minimal but flexion, extension and lateral flexion occur. The closed packed position of the facet joints being extension, the resting position can be found midway between flexion and extension. Normally the facet joints carry only a small amount of weight; with increased extension they become to have a greater weight-bearing function (Magee, 2002).

Anatomy of the underlying dysfunctions leading to intervertebral disc/ facet joint pathologies

Musculature

The spinal muscles have three main functions in relation to the spine: Extension, flexion, and stabilization of the spine, all of which are crucial to the golf swing. (Robinson et al., 2001; Luttgens & Hamilton, 1997). The only muscles of the spine that create rotation are the oblique muscle groups. Most of the spinal muscles run in a longitudinal fashion, parallel to the spine hence one can deduct that their function will be a product of their origin and insertion. When the required muscles are reasonably flexible, but without excessive flexibility, and well conditioned in terms of endurance, they have the potential to protect and unload some of the forces placed upon the spine, which otherwise can be injurious to the disc or facet.

Extending from the pelvis and sacrum upwards to the base of the skull, the Erector spinae are the main spinal muscles which are involved in spinal extension and stabilization. Included in the spinal muscle group is the Multifidus muscle which mainly prevents spinal rotation and helps protect the spine from rotational forces creating the torque (like the torque created during the golf swing).

The abdominal muscles perform the rotational movements and provide added stabilization required during the golf swing. All of the abdominal muscles (4) play an active role during flexion, extension, rotation and stabilization.
Table IX: Function of the abdominal muscles in spinal motion during the golf swing (Adapted from Luttgens & Hamilton, 1997; Watkins et al., Pink et al., 1993)

<table>
<thead>
<tr>
<th>Abdominal muscles “trunk muscles”</th>
<th>Function in the golf swing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus Abdominus</td>
<td>- Flexion of lumbar and thoracic spine during address</td>
</tr>
<tr>
<td></td>
<td>- One side works alone: lateral flexion of the spine, especially during the backswing and the forward swing</td>
</tr>
<tr>
<td></td>
<td>- Lower portion → shows more activity during the take away and the late follow through phases</td>
</tr>
<tr>
<td></td>
<td>- Upper portion → shows more activity during the progression of the swing</td>
</tr>
<tr>
<td></td>
<td>- overall reached its peak activity during the acceleration phase</td>
</tr>
<tr>
<td></td>
<td>- Involved during all phases of the golf swing</td>
</tr>
<tr>
<td>Obliques Externus Abdominus</td>
<td>- Flexion of the lumbar and thoracic spine, during address</td>
</tr>
<tr>
<td></td>
<td>- Lateral flexion of the spine during the backswing and the forward swing</td>
</tr>
<tr>
<td></td>
<td>- “Rotation” of the spine helping to store kinetic energy for the acceleration through the ball at impact</td>
</tr>
<tr>
<td></td>
<td>- Involved in all phases of the golf swing, highest activity shown during the take-away and follow-through phases</td>
</tr>
<tr>
<td></td>
<td>- Decelerates the trunk during the follow through phase</td>
</tr>
<tr>
<td>Obliques Internus Abdominus</td>
<td>- Flexion of the lumbar and thoracic spine as the golfer sets up for the shot</td>
</tr>
<tr>
<td></td>
<td>- Lateral flexion of the spine</td>
</tr>
<tr>
<td></td>
<td>- Rotation of the spine</td>
</tr>
<tr>
<td></td>
<td>- Involved in all phases of the swing, highest activity shown during the take-away and follow through phases</td>
</tr>
<tr>
<td></td>
<td>- Decelerates the trunk during the follow through phase</td>
</tr>
<tr>
<td>Transversus Abdominus</td>
<td>- Plays no role in moving the spine</td>
</tr>
<tr>
<td></td>
<td>- Actively involved in all phases of the golf swing, helping to stabilize the spine during the rotational motion of the swing</td>
</tr>
<tr>
<td></td>
<td>- Forms an integral part of the core muscles</td>
</tr>
<tr>
<td>Combination of all 4 muscles</td>
<td>- Overall the muscles have low activity during the take away phase (backswing) with the highest activity during the forward swing and impact phases</td>
</tr>
<tr>
<td></td>
<td>- Provides the stabilization golfer needs to stay “down” during impact and follow through</td>
</tr>
</tbody>
</table>

Other spine related muscles include the muscles of the hip and thigh which control pelvic rotation around the hip joint: Gluteus Maximus, medius, minimus, Hamstring group, Rectus femoris group, the adductors and abductors of the hip. If there is an imbalance amongst one of these groups, LBP could be a result.
V. INTERVERTEBRAL DISC & FACET JOINT PATHOLOGIES RELATIVE TO THE GOLF SWING

Intervertebral Disc Pathology

Degeneration of the intervertebral disc is termed spondylosis. The degenerative cascade describes this degenerative process of lumbosacral discs. Windsor describes the following 3 phases of the degenerative cascade according to Kirkaldy-Willis who identified the following:

The first phase, phase I, is known as the dysfunctional phase. This phase is characterized by circumferential tears or fissures in the outer annulus. In addition, endplate separation or failure can disrupt the blood supply resulting in the loss of nutrition to the disc. These changes are thought to result from repetitive microtrauma. One hypothesis is that the discs' nuclear proteoglycans lose the capacity to absorb water and maintain their protective function.

Phase II, or the unstable phase, is characterized by multiple annular tears (both radial and circumferential), internal disc disruption, and resorption or loss of disc space height. This phase is thought to result from the progressive loss of the mechanical integrity of the 3-joint complex.

Phase III also is known as the stabilization phase. Further disc resorption, disc space narrowing, endplate destruction, disc fibrosus, and osteophyte formation are present. Disc injuries are more likely to occur in phase I or II of the degenerative process.

Trunk rotation is associated with an increase in intra-discal pressure, a displacement of the nucleus toward the posterior wall of the annulus, where the supporting ligaments are thin and less protective, and twisting and sheer force on the fibers within the annulus. Repetitive rotation and flexion with the additional force of the golf swing itself contribute to excessive forces, which may ultimately result in tearing or fissuring of annular fibers. The nucleus, posteriorly located, is then predisposed to bulge or herniated. This may result in development of central back pain initially, and buttock or “sciatic” pain if ignored (discogenic low back pain, 2007).

Facet Joint Pathology

Osteoarthritis, also known as the term facet joint syndrome, suggests that hypertrophic changes secondary to osteoarthritis of the facets joint processes led to lumbar nerve root entrapment, which caused LBP (Malanga et al., 2006).

If one considers the disc and each of the adjacent facet joints as an interdependent functional spinal unit, degenerative changes within this 3-joint complex can influence each of the segments. Thus, degeneration of the discs can lead to loss of disc height, resulting in a relative increase in facet joint load found in compression and extension manoeuvres. One theory is that these excessive facet joint loads cause the inferior articular process to pivot about the pars and stretch the joint capsule, in addition to causing rostrocaudal subluxation (ie, facet joint malalignment). Thus, some authors postulate that facet joints undergo osteoarthritic changes in response to disc degeneration secondary to changes in loading (Malanga et al., 2006).

The Facet joints are diarthrodial joints with a synovial lining, the surfaces of which are covered with hyaline cartilage, which is susceptible to arthritic changes and arthropathies (Magee, 2002).

Repetitive stress and osteoarthritic changes to the Facet joint can lead to facet hypertrophy. Like any synovial joint, degeneration, inflammation, and injury can lead to pain with joint motion, causing restriction of motion secondary to pain, and thus deconditioning. In addition, Facet joint arthrosis, particularly trophic changes of the superior articular process, can progress to narrowing of the neural foramen (Malanga et al., 2006). In addition, as is the case for any synovial joint, the synovial membrane can form an outpouching and, thus, a cyst. Facet joint cysts are most commonly seen at the L4-L5 level (65%), but they are also seen at the L5-S1 (31%) and L3-L4 (4%) levels (Malanga et al., 2006). These synovial cysts can be clinically significant, particularly if they impinge on nearby structures (eg, the existing nerve root).
The neural foramen is bordered by the superior articular process, pars interarticularis, and posterior portion of the vertebral body. Facet joint hypertrophy or a synovial cyst can contribute to lateral and central lumbar stenosis, which can lead to impingement on the exiting nerve root. Thus, facet joint pain can occasionally produce a pain referral pattern indistinguishable from disc herniation.

In severe cases the following facet joint pathologies may occur spondylolysis (a defect in the pars interarticularis or the arch of the vertebra), spondylolisthesis (a forward displacement of one vertebra on another), or retrolisthesis (backward displacement of one vertebra on another) (Magee 2002).

Rotation and abrupt extension (arching), like in the golf swing, cause frictional and compressive forces. These forces may impinge or tear the facet joint capsule, and result in inflammation. This causes pain in the lower back, less often radiating down the leg. Because these joints have a rich nerve supply, and because of the tendency of “nerve” pain to be referred to other structures of common nerve supply, even people with facet pain may feel symptoms into the buttock or leg. Rarely, however, will symptoms be felt beyond the knee. In addition, unlike patients with disc symptoms, rarely should there be any sensory or motor complaint, or change in deep tendon reflexes (discogenic low back pain, 2007).

VI. GOLF SPECIFIC ASSESSMENT OF LOW BACK PAIN

General Assessment of Low Back Pain

Assessment is the process of documenting and evaluating patient-specific conditions. This is based on the theoretical concept of comprising objective and subjective information from the assessment into a treatment plan (Weed, 1968), which gets implemented in the practical build-up of the assessment. Physiotherapeutic assessment comprises an in-depth diagnostic approach based on detailed and systematic history and examination of all relevant systems, steps being: anamnesis, observation, physical examination (active, passive and resisted movements), and examination of the patient’s functionality in daily life, special tests, joint play and palpation. Supplemented by this is the collection of information about the patient’s cognition, emotional, social and psychological status. The purpose of the assessment finally is to clearly understand the patient’s problem, from the patient’s as well as the physiotherapist’s perspective, the physical cause leading to the patient’s complaints and the resulting care question of the patient (Magee, 2002).

In respect to specific low back pain especially the special tests help to clarify the differential diagnosis, as they give information about the kind of tissue causing the complaints. Special tests are considered as an integral part of the large examination process, however should never be performed in isolation because these tests depend on the personal skills of the examiner (Magee, 2002). For the assessment of the lumber spine Magee (2002) advises the straight leg rising test, the prone knee bending test and slump test should always be done especially in case of neurological symptoms.

Being able to return or continue to play golf is crucial for professional golfers suffering from complaints of the lower back due to overuse and who have been priory diagnosed with intervertebral disc and facet joint specific pathologies. This guideline will assist the physiotherapist in the decision making during the assessment by combining the review of literature of available assessment tools and the biomechanics of the golf swing

The following compiled evidence of assessment tools is used to differentiate facet joint/ intervertebral disc involvement from general low back pain and provides information about assessing the dysfunctions (links) specifically related to the golf swing. Further sub classification and differentiation of facet joint or disc pathologies is beyond this work.

Standardization of testing for better value

Strender et al. (1997) state that to evaluate reliability of clinical tests, it is important to make sure the tests are performed in exactly the same way by the examiners and that the limit of normality is defined. Many clinical tests, even if they have the same name, are performed and evaluated differently.
It is important that clinical tests do not get rejected because of low reliability that is caused by a lack of standardization of technique or of evaluation of test results (Strender et al., 1997). It has been suggested that experienced therapists develop unique strategies in performance and evaluation of clinical tests.

Anamnesis

A patient history with the medical and injury background should be taken and noted in the patient file to ensure reliability. The portion of the assessment with the greatest clinical relevance should be emphasised on (Magee, 2002). This portion of the guideline will point out information given by recent evidence based literature concerning anamnesis and assessment tests to differentiate between facet joint / intervertebral disc pathologies and general / non specific low back pain including the possible relation to the golf swing.

Intervertebral disc and facet joint pathologies

In the article by Humphrey and Eck (1999) the clinical evaluation and treatment options for herniated lumber discs are covered. They state that, if a disc herniation is responsible for the back pain, the patient can recall the distinct time of onset, by experiencing sharp, burning, stabbing pain radiating down the leg and below the knee on the posterior or lateral aspect, whereas if the pain is of gradual onset, other degenerative diseases are more probable than disc herniation. Discogenic pain can be further characterised by being superficial and local, and it is often associated with numbness or tingling. In the more severe cases, motor deficit, diminished reflexes or weakness may occur. Generally, only the relatively uncommon central disc herniation provokes low back pain and saddle pain in the S1 and S2 distributions. A central herniated disc may also compress nerve roots of the cauda equina, resulting in difficult urination, incontinence or impotence (Magee, 2002; Humphrey & Eck, 1999).

According to Humphrey & Eck, the most difficult aspect of evaluating patients with symptoms of a central herniated disc is differentiation between low back strain and herniated disc. Pain caused by low back strain is exacerbated during standing and twisting motions, whereas pain caused by central disc herniation is worse in positions like sitting that produce increased pressure on the annular fibers. The pressure on the intervertebral disc is increased during sitting and bending postures, as opposed to standing or recumbent positions. Magee (2002) explain that pain during coughing and sneezing is considered as a reliable sign of disc pathology, as it increases the pressure on L3 up to 35 %. Stankovic et al. (1999) on the other hand were not able to find a significant difference when comparing patient with and without disc pathology. Their results were that 73% of patients with disc pathology but also 66% without disc pathology showed positive signs on coughing. Thus care with the interpretation of this clinical sign must be given and no single conclusion should be drawn. Answers concerning the decrease and increase of pain in certain positions give information about the underlying cause. Pain increasing as a position is maintained for a longer time is associated with disc pathology, whereas constant pain during repetitive movements and morning stiffness but improvement through activity is an indicator for facet joint degeneration (Magee, 2002).

Physical examination

Active range of motion (ROM)

Lyle et al. (2005) found good inter-rater reliability in the performance of pain on active trunk motion (lumber flexion, extension and lateral flexion) in patients suffering from degenerative lumber conditions, therefore this part of the examination is also crucial in the examination of golf overuse injuries. Sufficient active range of motion is essential during the golf swing as it requires the spine to simultaneous flex, extend and rotate to great degrees. During the assessment it is important to note painful movements and limitations which occur. Magee (2002) describes that an increase of pain during lateral flexion to the painful side plus radiculation into the leg suspects a herniation of the intervertebral disc. In case radiculation are absent
the increase of pain may predict the involvement of the lumbar facet joints. The increase of pain during lateral flexion to the pain free side may predict a protrusion on the medial side of the nerve root, articular or muscular cause. Pain during extension and rotation, has to be examined with great attention and care as these are the typical movements of the golf swing and the closed packed position of the facet joints. In case pain is present a facet syndrome is foreboded at (Magee, 2002). Further in case the facet joints are the underlying cause of the complaints than low back stiffness, the absence of radiculation and neurological deficits, no hip or buttock pain, leg pain only above knee and the absence of paresthesia should all be results of the examination (Magee, 2002).

Vad and colleagues assessed trunk and hip flexibility in professional golfers by measuring the active range of motion of lumbar flexion, lumbar extension, bilateral hip rotation and the distance from knee to the horizontal table while performing Fabere’s test (hip flexed, abducted, and externally rotated) (Vad et al., 2004). (There is no detailed information about the reliability and validity of the Fabere’s test available). Fourteen golfers with a history of LBP for more than 2 weeks within the year prior to their measurements were compared to 28 control subjects. The results revealed that golfers with previous LBP had less lumbar extension angles than the control subjects. The LBP group also had flexibility deficits in the hip internal rotation angle and Fabere’s distance of the lead leg when compared to their non-lead legs. In the study of Lindsay and Horton, trunk rotation during the golf swing in golfers with LBP was observed to exceed their maximum voluntary trunk rotation in neutral posture (Lindsay & Horton, 2002). However, golfers without LBP rotated trunk within their maximum rotation range in neutral posture. Since there were no differences in the trunk rotation angle between golfers with and without LBP before normalizing to their maximum voluntary trunk rotation in neutral posture, the results of the Lindsay and Horton’s study imply that golfers with LBP need to increase their trunk rotation flexibility. Although these studies do not give information about the underlying cause of the LBP in their study populations, a decrease in active lumbar extension and rotation should be carefully observed and combined with other results for interpretation.

Humphrey and Eck (1999) found out in their study about “Clinical Evaluation and Treatment Options for Herniated Lumbar Disc” that pain during lumbar flexion suggests discogenic pain, while pain on lumbar extension suggests facet disease.

The findings of Stankovic et al. (1999) on the other hand, were that patients with disc herniations had significantly less range of movement during forward bending in standing and higher pain distribution in the leg during backward bending in standing. Agreement between clinical and radiological findings for type and level diagnosis of disc hernia was found in 72 out of 105 patients (68.6%). Lumbar range of motion on forward bending in standing and pain distribution during backward bending in standing even were the strongest predictors among 25 different clinical variables in order to determine patients with the presence of disc herniation.

**Proprioception / Postural stability**

The clinical assessment of joint position sense can be difficult and its validity has been questioned (Warren et al., 2006) while the cost of sophisticated balance systems may limit access for many practitioners. One common clinical approach to the measurement of proprioception and static stability is that of single leg stance test (SLST), also referred to the Romberg test, where the patient is required to maintain balance while standing on one leg for 20 seconds (Magee, 2002). Hertel et al. (2000) further employed the Star Excursion Balance Test (SEBT) as a validated measure of dynamic balance ability which, unlike force plates or electronically controlled balance platforms, is a simple and highly portable test that could be employed in a range of clinical environments.
Passive Range of Motion

Little is stated in literature concerning the performance of passive movements of the lumbar spine. Generally passive movements are difficult to perform due to the weight of the body and difficulty isolating the lumbar spine from the surrounding joints. Therefore the assessment of the end feel is advised during joint play assessment of the individual vertebrae of the lumbar spine, as it is safer (Magee, 2002).

Muscle testing

The selection of muscle strength testing should be based on the function of muscle performance during the tasks (i.e. the golf swing), such as maintaining the joint stability, posture, or the dynamics of motion. Since the golf swing is complex in nature and involves a considerable amount of trunk rotation and powerful muscle contractions, it is important to test each of the involved muscles (see golf biomechanics section). The modern golf swing restricts the hip turn to build torque in the back and shoulders during the backswing for maximum club head velocity at ball impact (Hosea & Gatt, 1996).

The abdominal muscles are active considerably during the golf swing and are active in the acceleration phase to generate power (Horton et al., 2001). Considering the contributions of the trunk muscles in rotation and lateral bending movements and the repetitive nature of the game of golf, it is possible that muscular fatigue could develop during game or practice (Horton et al., 2001). The relationship between muscle deficiency and chronic low back pain (CLBP) is not clearly understood, especially in golfers, however it is known a lack of strength and endurance of the trunk muscles appears to be a significant risk factor in the development and occurrence of CLBP (Horton et al., 2001). Although the abdominals and low back muscles work together to rotate the trunk and stabilize the lumbar spine, the abdominal muscles tend to fatigue more easily, especially in individuals with CLBP (Horton et al., 2001), hence abdominal fatigue should be assessed.

Hip muscles play an important role in stabilizing the movement of the pelvis during the golf swing. Trunk muscles are responsible for rapid torso rotation, flexion, extension, and side bending in one combined movement. Thus, the measurement of isometric hip muscle strength and isokinetic trunk muscle strength would be appropriate for assessing the strength differences between golfers with and without LBP. Furthermore, it was suggested that rapid motion seems to be able to discern the loss of muscle function in patients with LBP better than slow motion (Ljunggren, 1993). Isokinetic test at slow speeds, however, are considered to reveal articular problems (Ljunggren, 1993). Evaluation of trunk strength at both fast and slow speed would provide more information regarding back problems in golfers with LBP as compared with their healthy counterparts.
Specific muscle test

Magee as well as Kendall et al. advice various trunk muscle tests to collect information about endurance and power of the different muscle groups. Although no further differencing information out off the current literature is present, the physiotherapists should select from the following:

- Dynamic abdominal endurance test
- Double straight leg lowering
- Internal/external oblique test
- Dynamic horizontal side support test
- Dynamic extensor endurance test
- Isometric extensor test
- Back rotator/multifidus test

* Among the great variety of muscle strength and endurance tests, only evidence about the following is available:

Isometric extensor endurance test

Moreau et al. reviewed available literature on the validity and reliability of isometric endurance tests for the extension of the lower back. They found the prone isometric chest raise test to have high reliability in the testing of healthy and LBP patients and only a moderate test re-test reliability. Coming to validity no valuable conclusion was drawn.

The most common test for trunk extensor endurance is the Biering-Sorensen test of trunk extensor endurance. Latimer et al. (1999) and Allison and Henry (2001) agreed upon a high reliability between trials and satisfactory intra-observer reproducibility in healthy and LBP individuals. The test-retest and inter-rater reliability for the Biering-Sorensen test examined in a study by Moreau et al. (2001) were moderate till high and intra-class correlation was also high for active LBP patients. Moreau et al. resultanty characterized this test as a global measure for the back extension endurance capacity. Further it was found that the test has a high sensitivity in between individuals (Latimer et al. 1999; Allison & Henry 2001).

The detailed data from Allison and Henry would suggest that the rectus abdominis and internal oblique (both flexor synergists) tended to demonstrate a reduced fatigue easily during the back extension task. This would indicate some level of muscle fatigue. During the extension task performed in this study, subjects had their pelvis stabilized with a rigid support creating an extensor moment about the pelvis. The rectus abdominis and internal oblique co-activity may stiffen the spine to reduce small-amplitude high-frequency perturbations or large amplitude movements across multiple segments. In mathematical models of the role of trunk muscles in spinal stability it has been shown that co-activation of the antagonists (three most superficial muscles) increases stability but this is associated with an increased fatigue rate (Stokes, 1998). Allison and Henry predict that the activation of the superficial abdominal muscles may provide stability at the expense of the back extension performance. It is possible that individuals with LBP may have an increased level of co-activation and therefore fatigue faster than normal or they have less co-activation and therefore may present with a poor performance due to poor extension muscle capacity. The data from this study of healthy individuals demonstrates that if there are fundamental differences between back extensors performance then it may be impossible to attribute a poor performance to low muscle capacity without controlling for abdominal muscle co-activation patterns. For example, two individuals may present equally with poor back extension endurance, yet one individual with spinal stability problems may perform poorly since the co-activation of antagonists (flexors) may increase the rate of fatigue whereas the other may have poor back extension capacity due to detraining. Similarly, it follows that such tests, although with demonstrable ability to differentiate between individuals with chronic LBP and healthy subjects, may not explicitly define the underlying impairment. This is an important factor for therapists to consider and has significant implications for goal setting in rehabilitation programs (Allison & Henry, 2001).
Moreover, the study by Keller et al. (2001) reported a high reliability in the assessment of LBP patients with the Biering – Sorensen test but not in healthy individuals. Importantly the reliability outcome depends on the kind of scale used for statistical analysis and interpretation, as Keller et al. found differences in the assessment of reliability depending on the method used (critical difference or the intra class correlation). The influence of the hip extensors, superficial and deep abdominal muscles during the test of the back extensors as well as the detection of LBP prediction with the help of this test, should be kept in mind but are not clarified yet.

In addition to the flexibility investigated by Vad et al. and Lindsay and Horton, tight hip extensors and hamstrings may decrease lumbar lordosis and tight hip flexor may increase lumbar lordosis (Neumann, 2002). Thus special attention to the flexibility state of the muscles around the pelvis should be given. Magee refers in this context to the lumbar or pelvic crossed syndrome described by Janda and Jull (1987). The patient is not able to maintain a neutral position of the pelvis due to muscle imbalance, the erector spinae, hamstrings and Iliopsoas being tight while the abdominal and gluteal muscles are weak and lengthened.

**Functional assessment**

The clinical question posited as a goal by a professional golfer with low back pain owing to discal and facet joint pathologies can be demanding and complex in nature. A biomechanical assessment of the golf swing may include analysis of movement and muscle activation patterns as well as internal and external forces (Hume et al., 2005). Biomechanics is used to characterise the “ideal” golf swing, with the aim of improving performance and reducing the risk and severity of golf-related injuries (Dillman & Lange, 1994). Functional assessment can be complex in nature (Quantitative Golf Kinematics), or more basic in nature (Qualitative Golf Kinematics). “You don’t have to play golf to treat golfers, you don’t even need to like golf” (Blanchard, 2007).

With sound knowledge of the biomechanics of the golf swing and the structures involved, a physiotherapist can assess the golfer qualitatively. Qualitative Golf Biomechanics gives the therapist/coach/biomechanist the ability to observe a golf skill being performed, evaluate its effectiveness and give appropriate feedback to the golfer (Hume et al., 2005). By breaking up the swing into phases and analyzing the key elements involved, the therapist can use his/her theoretical model of how the skill should be performed based on mechanical principles (detailed above in the golf swing biomechanics section) in combination with the observed skill to evaluate the problem. Once the observed skill of the patient is compared with the theoretical desired swing, the problem is determined (Hume et al, 2005). The cause of the problem is just as important as the effect and once the problem is found, the physiotherapist can then come up with a plan to action. The key elements in each phase of the swinging movement must refer to specific body movements and must be observable. The observation plan should be indicated: from which angle will the swing be observed? What parts of the body will be examined? And how many times will the skill be performed for evaluation? (Hume et al., 2005)

Age, skill level (handicap/ranking), efficiency, anatomy, and athletic background are taken into account to make the evaluation as patient specific as possible. Factors such as previous injury, hours of play, environmental factors, and anxiety levels asked during the history taking are taken into account. Hume et al. (2005) state that the patient should be observed in an environment mimicking as closely as possible the competitive environment which the athlete in participates in. In one study, the authors used a computer-based videotape analysis system to present a randomised series of golf swings to ten coaches of professional golfers and ten coaches of amateur golfers. Both groups had similar abilities in identifying the main characteristics of the swing, but their model of the “correct” swing was influenced by the observed golfer’s skill level (Sherman et al., 2001). It is important that the therapist have a well-read background of the biomechanics of a golf swing so that their assessment is based on sound mechanical principles and not subjective judgements of skill level (Hume et al., 2005).
Dr. Jeff Blanchard (2007) created a 14-point flexibility examination, which is easy to use yet holds little evidence based proof. That being said, given his expertise and experience in the field, we find Blanchards’ assessment techniques worthy and valuable to note. ‘The Cannonbal’ assesses basic spinal flexion (patient is seated at the edge of a chair and asked to tuck their chin to the chest and wrap the arms around the knees and hold for 1 minute). For hamstring tightness, the “Toe touch” test is used: asking the patient to bend over and reach to touch the toes (also holding for one minute). Side flexion, rotation and extension are also parts of Blanchards’ assessment examination using simple functional examples:

Side flexion (bilateral stretch held for 1 minute): patient stands with the palm of their hands to their sides and is asked to slide their hands down the side of their thigh until the fingertips reach the knee without rotation of the torso. If the patient cannot bend laterally, their torso will move up and down while swinging the club and jeopardize their ability to keep their extended left arm parallel to the plane line when swinging the club.

Rotation: making sure rotation is equally bilateral for if not, patients are more prone to injury.

Extension (hold for 1 minute): using a Swiss ball, the patient lies down in extension with their head in contact with the ball, knees flexed at 90 degrees and heels on the ground with no pain. Extension of the lumbar and thoracic spine is needed to keep the club shaft “on plane” after impact with the ball, and extension of the entire spine is necessary to hold the finish position.

Per swing analysis, Blanchard stresses the need to look for and identify 3 key points in the patients’ golf swing:

1. Is the position of the back foot perpendicular to the plane line? (to ensure a directional release of energy directly toward the intended target; the open back foot permits over-rotation of the lumbosacral spine.)

2. Does the extended forward arm trace parallel to the plane line during the backswing and the downswing? (When a golfer swings safely, the kinetic energy is released directly toward the intended target. Because the Plane Line is continuous with the target line, it should make sense that the forward arm should sweep parallel to the Plane Line to release the energy of the body directly toward the target).

3. Does the club shaft point the plane line throughout the swing? (With this position, the golfer can coil and then release his stored kinetic energy directly toward the intended target.

Injuries to the lumbar spine due to golf greatly affect the patient's ability to function also outside of golf. In order to support and treat the patient sufficiently his functional capacities must be assessed. Out of a variety of screening tables, the Oswestry disability questionnaire (appendix D) is one of the most widely used ones (Davidson, 2007). The Oswestry disability index is a good functional scale because it deals with activities of daily living and is therefore based on the patient’s responses and concerns affecting daily life (Magee, 2002). In the "Rasch analysis of three versions of the Oswestry Disability Questionnaire" Davidson favours the standard version of the Oswestry and the version that replaces Sex Life with Work/Housework, as both form uni-dimensional scales in which all items are measuring a single underlying variable. The disability index is calculated by dividing the total score by the number of sections answered and multiplied by 100 (Davidson, 2007).
Quantitative golf kinematics is difficult for the average physiotherapist to perform due to the fancy and expensive equipment and tools used to analyze the golf swing. It provides numerical data on the body angles and movements during the golf swing. These angles are usually gained from video analysis where a video image is captured onto a computer and a programme determines the angle by a process called digitising (3D analysis) and is preferred for research (Morgan et al., 1998). This type of assessment is beyond the scope of this document since it is not used by the average practicing physiotherapist.

Regardless of the strategy used to analyse the golfers’ swing, it is most important for the patients to state their goals clearly.

**Special tests**

Special tests are considered as an integral part of the large examination process, but should never be executed in isolation because these tests depend on the personal skills of the examiner (Magee, 2002). For the assessment of the lumbar spine Magee advises the straight leg rising test (SLR), the prone knee bending test and slump test should always be done especially in case of neurological symptoms. Magee (2002) advises therapists to develop skills in 2-3 tests effectively and widen the understanding of how neurological tissue is being stretched and which neurological tissue in particular is demonstrating signs and symptoms.

The following list of special tests is by no means a full and complete list of all available tests. The tests described below are those which the authors found to be most efficient, practical and which were evaluated by evidence based means, hence serve the purpose of the guideline to follow.

**Straight leg raising/ Lasegue test**

Nerve root tension signs are often used in the evaluation of patients suspected of having a herniated disc. This test evaluates the mechanical movement of the neurological tissue and tests the sensitivity to mechanical stress or compression. Deville et al. report in their systematic review of the accuracy in diagnosing herniated discs, a low specificity but a high sensitivity of the SLR, which equals the results from Vroomen et al. (1999). Lyle et al. (2005) add a satisfactory reliability between raters to these results. In 1992, Deyo et al. rated the SLR test as the most appropriate test for the lower lumbar nerve roots. However it did not get a better attribute than moderately accurate from Van den Hoogen et al. (1995).

The active straight leg raising / Crossed straight leg raising

Murphy has shown the active straight leg raising to be valid and reliable. As did Mens et al. who discovered the test to have a good reliability and validity, although it was not clear if this is only true for pregnant women or not.

A crossed straight-leg raising test may also suggest nerve root compression. In this test, straight-leg raising of the contra-lateral limb reproduces more specific but less intense pain on the affected side. In the systematic review of Vroomen et al. the crossed straight leg raising scored high specificity but low sensitivity.

**Slump test**

The slump test also evaluates the movement and mechanical properties of neurological tissue. Stankovic et al. (1999) found moderate specificity but high sensitivity. Therefore also this test should only be executed with a great deal of careful, sensitive handling and interpretive skills (Stantikov et al. 1999). Nelson et al. (1979) report the general reliability of this test as low, this is not supported by Stankovic as their findings report high interrater reliability. Stankovic et al (1999) looked at pain distribution during slump test and found that patients with disc herniation had more pain distribution in the leg during slump test compared with the patients with bulging discs and patients without positive findings, but the differences were not significant.
Quadrant test

The quadrant test is a combination of active movements assessing for facet joint dysfunction in the lumbar spine. This test is a high predictor of symptom severity and the most common test to reproduce the patients’ symptoms, as it distinguishes those subjects with clinically meaningful low back pain symptoms but does not directly predict impaired function (Lyle et al., 2005). In the study about inter-examiner reliability in physical examination of patients with low back pain Strender et al. (1997) report high inter-rater reliability of the quadrant test.

Schöber test / modified- modified Schöber test

The Schöber test is a test frequently performed to measure the sagittal lumbar spine range of motion in centimetres and it has been also modified since its development. Stankovic et al. (1999) revealed in their study of the use of lumbar extension, slump test, physical and neurological examination in the evaluation of patients with suspected herniated nucleus pulposus, that the test had a high intrarater and interrater reliability.

Tousignan et al. (2004) on the other hand examined the Modified- modified Schober test, which serves the same purpose but is slightly altered compared to the original test. This study resulted in a moderate validity but an excellent reliability. Compared to the golden standard of X-ray measurements Littlewood and Mayb (2006) found no proof that the test is not valid in their systematic review.

Hip extension test

There are two tests available using hip extension to evaluate motor control of the lumbar spine and secondly testing the femoral nerve. Humphrey and Eck (1999) refer to the femoral stretch test as an evaluation tool for the reproducibility of pain. In this test, the patient lies in either the prone or the lateral decubitus position. The thigh is extended at the hip, and the knee is flexed. Reproduction of pain suggests upper nerve root (L2, L3 and L4) disorders.

Murphy et al. (2005) on the other side describe the extension test with a different purpose, namely suspecting impaired motor control of the lumbar spine. It has been the clinical experience that, in using this test, a common finding in patients with chronic LBP is that of deviation of the lumbar spine from the neutral position during the raising of the leg. This typically took 1 of 3 forms: (1) rotation of the lumbar spine such that the spinous processes appeared to move toward the side of hip extension; (2) lateral shift of the lumbar spine toward the side of hip extension; or (3) extension of the lumbar spine. Furthermore, it was commonly found that when the patient was taught to perform a maneuver designed to co-contract the deep segmental stabilizing muscles (primarily transverse abdominis and multifidis) and hold this maneuver during the performance of the hip extension test, the lumbar deviation would appear to decrease. If this did not improve the test, teaching the patient to superimpose the contraction of the larger stabilizing muscles of the trunk (erector spinea, rectus abdominis, and external oblique) on the contraction of the deeper muscles would usually bring about reduced deviation. This raised the question as to whether the finding of deviation of the lumbar spine on the hip extension test may be a sign of impaired motor control, or dynamic instability, in the lumbar spine. It was hypothesized by Murphy that perhaps the deviation of the lumbar spine that often occurs during the hip extension test represents inability of the stabilizing system of the spine to properly perform its function in automatically ordering co-contraction of the stabilizing muscles in response to perturbation, here in the form of the raising of the leg. In their study, which dealt with the inter-examiner reliability of this test, Murphy found a good inter-examiner reliability in detecting deviation of the lumbar spine from the midline, as well as validity in regard to the tests ability to distinguish patients with chronic low back pain from normal individual. Yet no information is provided about the underlying cause of the chronic low back pain.
Revel’s criteria

One of the few screening tests for the assessment of the facet (zygapophysial) joints is the so-called Revel’s criteria. This test is a combination of standing flexion, returning from standing flexion, standing extension and finally extension and rotation (Laslett et al., 2004). The study of Laslett et al. (2004) examined this test showed to have low sensitivity and high specificity. Nevertheless the examiners concluded from these results, that the test is unsuitable as a clinical screening test to evaluate chronic low back pain. Maher et al. support this statement, as they found in their systematic review that the results of studies investigating the facet joint as the source of a patient’s symptoms suggest that the currently available tests have limited or no diagnostic validity. Maher et al. present studies of ‘Revel’s criteria’ in which results were conflicting, therefore no advice in the practical use of this test can be given.

McKenzie / lumbar extension test

Stankovic et al. (1999) retrospectively report a study using a clinical sign to evaluate and treat patients with acute herniated nucleus pulposus according to the McKenzie principle (1981). They reported that in 94% of the patients who were unable to reach normal lumbar extension, disc hernia was found at operation. They further used this clinical sign prospectively to determine if it is possible to identify patients with disc herniation. Among the 105 patients, 91 (86.7%) had movement loss of extension in lying. Forty-seven patients (90.4%) with disc herniation had movement loss of extension in lying compared with 35 patients (85.4%) for those with bulging discs and nine patients (75%) without positive findings, but the differences were not significant. Twenty-one per cent of the patients with disc herniations shown on CT/MRI examinations had major movement loss of extension in lying, compared with 6% of patients with bulging discs. In the present study 21 patients with disc herniation had in addition the presence of spinal stenosis and intervertebral joint hypertrophy.

Magee describe the McKenzie side glide test in standing, where also an increase in the neurological symptoms is provoked due to a prospected involvement of the intervertebral disc. From both authors no information concerning reliability and validity of these tests are given.

Reflex testing

Testing reflexes is a common procedure in the assessment of patients with neurological involvement such as damage to the intervertebral disc, especially in the more advanced cases (Magee, 2002; Humphrey & Eck, 1999). Stankovic et al. (1999) detected that 38% of patients examined had impaired or absent reflexes. The achilles reflex was weak in 48% and absent in 28%. The patellar reflex was weak in 8%. However, the symptoms do not always provide a clear diagnosis of the level. The absence of an achilles reflex is more indicative of disc prolapse than impairment of this reflex (Stankovic et al., 1999). In the present study no significant differences between groups were noticed for muscle weakness, sensory impairments or reflex depressions.

VII. PREVENTION

The available scientific literature suggests different kind of exercise types to prevent golf related lower back injuries: warm up, strength, flexibility and cardiovascular exercises (Fradkin et al. 2001; Fradkin et al., 2004; Lehmann, 2005; Reed, 2005). Lower back pain as a result of a golf swing often arises from two different sources: (a) overuse of muscles in the trunk and (b) poor physical condition of these muscles (Pink, 1993). Good physical conditioning permits reasonably prolonged golf practice each week throughout the year without harm, and helps to prevent overuse injuries in particular (Theriault & Lachance, 1998).
Table X: The effect of conditioning programmes on golf performance. All results are mean ± standard deviation (where reported) (Hume et al., 2005)

<table>
<thead>
<tr>
<th>Study</th>
<th>Subjects</th>
<th>Training type</th>
<th>Duration</th>
<th>Frequency</th>
<th>Change in performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hetu et al.</td>
<td>n=17; age 52.4 yrs HCP?</td>
<td>Strength and flexibility</td>
<td>8</td>
<td>2</td>
<td>Increased club head velocity</td>
</tr>
<tr>
<td>Jones</td>
<td>n=16; age 58 ±9 yrs; HCP 18 ±7</td>
<td>PNF stretching</td>
<td>8</td>
<td>3</td>
<td>+7.2% club head velocity*</td>
</tr>
<tr>
<td>Larkin et al.</td>
<td>n=4; age?; HCP?</td>
<td>Strength and flexibility</td>
<td>3</td>
<td>?</td>
<td>+45% trunk rotation power*</td>
</tr>
<tr>
<td></td>
<td>n=4; age?; HCP?</td>
<td>Control</td>
<td>3</td>
<td>0</td>
<td>+7% NS trunk rotation power</td>
</tr>
<tr>
<td>Lennon</td>
<td>n=7; age 16 ±4 yrs; HCP?</td>
<td>Strength and flexibility</td>
<td>8</td>
<td>4</td>
<td>+5-iron distance (a)</td>
</tr>
<tr>
<td></td>
<td>n=7; age 16 ±4 yrs; HCP?</td>
<td>Control</td>
<td>8</td>
<td>0</td>
<td>NS (Siron distance) (a)</td>
</tr>
<tr>
<td>Westcott et al.</td>
<td>n=17; age 57 yrs; HCP?</td>
<td>Strength and flexibility</td>
<td>8</td>
<td>3</td>
<td>+6% club head velocity*</td>
</tr>
<tr>
<td></td>
<td>n=5; age? HCP?</td>
<td>Control</td>
<td>8</td>
<td>0</td>
<td>0% NS club head velocity</td>
</tr>
</tbody>
</table>

(a) Although significance was discussed, no actual distances were reported  
HCP = Handicap; NS= non-significant (p> 0.05); PNF= proprioceptive neuromuscular facilitation; + indicates increase;* indicates p< 0.05;? indicates unknown.

Warm Up

The term warm up is defined as a period of preparatory exercise in order to enhance subsequent competition or training performance. The purpose of a warm up is to prepare the body both physiologically and psychologically, while at the same time reducing the risk of injury (Fradkin et al., 2004). Although there is a lack of scientific evidence to link warming up to reduced injury risk, literature agrees upon the belief that a properly conducted warm up procedure reduces the chance of injury during golf (Fradkin et al., 2004; Lehmann, 2005; Reed, 2005). However, as the benefits of golf warm up procedures have not been formally studied, the current recommendations for such activities are inconsistent. What is clearly known are the physiological reasons for warm up exercises, which include the increase in body and muscle temperature which cause an increase in enzyme activity and thus the metabolic reactions associated with the energy systems, the increase in blood flow and oxygen availability, and decrease in contraction and reflex time (Foss & Keteyian, 1998).

Fradkin et al. collected information about the proportion of golfers that warm up and to determine the types of warm up they undertake. They examined the warm up behavior of 1040 amateur golfers in their study “Warm up practices of golfers: are they adequate?” and concluded that warm up behaviors of these 1040 golfers immensely differ from each other and that warm up behavior depends on the individual golfer. Further, they suggest that an appropriate warm up for golfers should include a period of aerobic exercise to increase body temperature, followed by stretching of the “golf muscles” (hands, wrists, forearms, shoulders, lower back, chest, trunk, hamstrings, and groin). A series of golf swings with a progressive increase in range of motion and vigor should then be performed (Fradkin et al., 2001), progressively starting with the short clubs going over to the longer ones. In another study by Fradkin et al. (2004) two groups of golfers were compared in respect to their club head velocity. The intervention group undertook a 5 week warm up program consisting of three parts: exercises increasing body temperature, static stretches and air swings with the golf club, whereas the control group continued their normal golf routine. The results present that golfers’ performances will be significantly improved by undertaking a golf specific warm up program compared with not performing the warm up, as the club head velocity of the intervention group significantly increased compared to the control group (Fradkin et al., 2004).
Specific activities that can be utilized in the warm-up include calisthenics such as jumping jacks and running in place for 10 to 15 minutes prior to swinging a golf club (Reed, 2005). Hartman et al. suggests 5-15 minutes of walking, cycling, easy jogging to increase muscle and core temperature. In addition Blanchard (2007) recommends pelvic twist for proper alignment and unrestricted movements are important for balance and power, 5-10 times on each side. Patient places feet straight ahead and directly under his hips. He is to holds the shaft of his driver against the small of his lower back, palms facing forward. He then tilts his spine slightly forward from the waist. As he slowly rotates to the left and right, he keeps his weight on the inside of his feet. The forward curve in his lower back should be maintained.

**Cardio-Respiratory Fitness**

Endurance, according to Foss and Keteyian (1998) is the time limit of a person's ability to maintain either an isometric force or a power level involving combinations of concentric and/or eccentric muscle actions. Maintaining endurance activities is therefore heavily dependant upon the aerobic synthesis of Adenosine Triphosphate (ATP) requires an adequate delivery of oxygen to oxidase in the mitochondrial electron transport chain and the supply of fuels in the form of carbohydrates and lipids (Foss & Keteyian, 1998).

In the design of a golf-specific conditioning program, all of the above-mentioned factors should be addressed because as in other sports, fatigue is among the major factors that decrease performance in golfers (Russel & Owies, 2000). The high skill level required, combined with the small margin for error with each shot, means that even a small level of fatigue may greatly decrease performance. Factors such as concentration, neuromuscular coordination and muscle strength will eventually be influenced by fatigue. An increase in the level of cardio-respiratory fitness will enable the golfer to complete a round of golf feeling less exhausted and thus better able to continue to execute the many golfing skills to prevent fatigue Hartman et al. (2004) advise cardio-vascular exercises 3-4 times a week for 30-40 minutes to in turn build up aerobic/cardio-vascular/respiratory endurance.

**Flexibility**

Flexibility is the range of motion about a joint and its surrounding muscles; this is also known as static flexibility, whereas dynamic flexibility refers to the resistance of a joint during movement (Baechle, 1994). Good flexibility is essential for playing golf (Russel & Owies, 2000). Golfers need a good range of motion of the lumber spine, flexibility of the trunk and hip musculature, spinal rotation and shoulder mobility to successfully execute the golf swing (Vad et al., 2004). Appropriate flexibility can decrease the resistance in various tissues in the trunk and hip muscles and prevent the changes of normal lumbar curvature caused by tight muscles. A golfer with appropriate flexibility is therefore less likely to sustain injury by exceeding tissue extensibility during the golf swing. This may then decrease the forces applied to the lumbar spine (Lindsay & Horton, 2002).

Hartman et al. advise the following stretches to be executed prior to a round of golf (3-4 times per week), as prevention for golf related back injuries:

* **Holding time of each stretch is 20-30 seconds, repeated 2-3 times. The stretches are performed in a slow, controlled manner, with no pain and natural breathing pattern:**

  **Cat stretch:**  Patient in the quadruped position, flexion/extension stretch by tilting the pelvis and alternating arching and depressing the back

  **Knee to chest sequence:**  Stretch of the lumbar paraspinal muscles and hip extensors, through pulling on knee to the chest and the head and neck to the knee while lying supine. This can also be done by pulling both knees simultaneously towards the chest

  **Prayer stretch:**  Starting in the quadruped position with the back held flat the patient sits down onto the heels and stretches the arms out in front.
Spinal rot: The patient starts in the supine position with the knees bent to stretch the lumbar musculature and rolls both knees as close to the floor as comfortable. Secondly the legs are extended again and one leg is raised and lowered across the body to rotate the trunk.

Hamstring stretch: This stretch is especially important, as the hamstring length can determine the lumbar spine position. Firstly the leg is elevated unto a chair or something equivalent with comfortable height, while the knees and the back are kept straight during forward bending until a slight pull is felt in the hamstrings.

Strength

The aim of strength exercise is to improve the strength of the golfer and their ability to generate power during the golf swing to increase club head speed. Due to the muscular demands of the golf swing and the prevalence of injury in the lumbar spine, training the trunk musculature may improve performance and decrease injury risk (Hartman et al., 1998). Exercises performed in the injury prevention component may improve the golf swing and exercises performed during the strength and power component may reduce the risk of injury. Pink et al. hypothesized that strong back muscles may even directly reduce the risk for golf-related injuries.

Physical inactivity has been associated with reduced strength of the muscles of the trunk, and a direct correlation has been established between inactivity and chronic lower back pain (Reed, 2005). According to Reed the erector spinae and abdominal oblique muscles play a vital role and are utilized most in the golf swing. It is not surprising therefore that the majority of golf injuries occur at the location of these two large muscle groups. These muscle groups function to initiate and control the body while the golfer is performing the swinging motion. The repetitive swinging of the golf club can lead to fatigue in these muscles, increasing the risk for injury not only to the back, but also to secondary muscles as well (Reed, 2005).

Adequate spinal stability is the amount of trunk muscle co-contraction necessary to reinforce the spine to prevent segmental buckling. This ability to stabilize the spine is considered necessary in the prevention of low back injuries (Panjabi, 2003) Spinal stability is not provided by one specific muscle but rather via the coordinated efforts of the flexor, extensor and lateral bending trunk musculature (rectus abdominis, external oblique, internal oblique, transverse abdominis, erector spinae, quadratus lumborum and latissimus dorsi) (Hartman, 1998). Because only a minimal level of trunk muscle contraction appears necessary to stabilize the spine, the strength of these muscles appears less important than the endurance capabilities of the muscular stabilizing system. Hartman states that spinal extensor endurance has been shown to be correlated with a decrease in injury risk for the lumbar spine, as well as aberrant flexor/extensor endurance ratios. Therefore, the aim of a golf exercise program is to improve the endurance and strength of trunk muscles to further facilitate their ability to stabilize the spine in neutral and non-neutral positions and improve their ability to produce force during the golf swing (Lehman, 2006).

* These strengthening exercises advised by Lehman, 2006 are golf specific but require a gym and equipment.

Cable punch: This exercised is performed standing with the legs slightly bent, staggered and body weight on the balls of the feet. While keeping an athletic posture the golfer begins with the cable held lateral to and slightly in front of their chest. The golfer than presses their hand forward in line with the cable. The exercise creates an isometric torque about the lumbar spine which the golfer must resist while actively contracting the primary movers (pectoralis major and triceps brachii). The golfer can also make a slight twisting motion similar to throwing a punch or a football. In addition to training the primary movers this exercise requires a great deal of trunk muscle activity. The twisting motion is similar to the rotation occurring during the golf swing.

Lawnmower Pull: With the knees bent between 45 and 90 degrees and the feet staggered (left leg forward if pulling with the right arm) the golfer faces the weight stack and pulls the cable toward the chest like a one arm row. During the pulling action the knees should extend and the golfer should now be upright. A small amount of trunk twist should also occur during this movement.
Weighted golf swing: The golfer grips the rope attachment with two arms and mimics a slow and shortened golf swing. The arms should travel less than 30 cm. The golfer must focus on the trunk starting the movement and the proper weight shift from the trailing leg to the lead leg. This exercise is not designed to allow for a swinging of the arms, rather a small movement of the trunk twisting combined with a small amount of arm movement should occur.

Reverse scaption: Using the trailing arm (the right arm for a right handed swinging golfer) the athlete grasps elastic tubing or the cable with their arm abducted and external rotated. This position should be similar to the midrange position of the downswing. From this position the athlete should adduct their arm as if attempting to swing. The elbow should not cross the midline of the body and should finish “tucked” against the athlete right side.

Medicine ball toss: The golfer simply assumes a golf stance, swings the ball back similar to the back swing but not more than halfway back and then swings forward releasing the ball while attempting to mimic the proper golf movement.

Deadlift: This exercise is designed to train the leg muscles and the posterior trunk muscles. It should also be noted that all abdominal muscles are recruited and this is therefore an excellent “core” exercises. Golfers should focus on allowing the buttocks to feel as if they are being pushed backwards. Body weight is on the heels similar to the golf address position. This exercise is added because it is an excellent all around exercise and is similar to the address position for all swings of the club.

Prone isometric abs: Lying face down on the floor with feet together and forearms on the ground, the patient clenches the hands in a fist at shoulder level. Then he draws the abdominals inward and squeezes the gluteal muscles and lifts the body off the floor forming a straight line from head to toe resting on the forearms and toes. The patient holds this position, and then extends one hip by activating the gluteal muscles and lifting one leg off the ground, putting the leg in triple extension (hip, knee, ankle plantar flexion). Then slowly the patient returns the body to the ground with the chin tucked and back flat.

Quadruped arm opposite leg raise: The patient begins in the quadruped position with the abdomen drawn in and the chin tucked. Slowly one arm with the thumb pointing skyward is raised and the opposite leg pointed away (triple extension). The arm and leg are kept straight while lifting to body height. This position is held and then the arm and leg slowly returned to the ground, while maintaining proper alignment. Alternating repetitions are performed with each leg.

Floor two leg bridge: The patient lays flat on the floor, knees bent, feet flat, toes pointing straight ahead and arms by sides. Then the activate gluteal muscles are activated and hips are raised off the floor to form a straight line. This position is hold and the hack slowly returned to the ground.

Floor prone cobra: The patient lays face down on the floor with arms in front of the body and palms facing down. Then the gluteal muscles and abdominals are activated and the scapula retracted towards the midline of the body, lifting the chest off the floor while keeping the chin tucked. This position is held and then slowly the upper body is return to the floor.

Ball bridge: The patient lies on the back with a stability ball between the shoulder blades. The knees are bent, feet pointed straight ahead at shoulder-width. The abdomen is drawn in, activating the gluteal muscles, and lifting the pelvis until the knees are bent 90 degrees and a straight line can be drawn from shoulders to knees. This position is held and then slowly pelvis is lowered back toward the ground.

Scapular retraction: Strengthening the upper back and stretching the anterior chest, as the patients stands the scapulae are squeezed together and held for 20-30 seconds before returning to the starting position slowly. The patient has to maintain a good upright posture while performing the exercise.
Wood chopper plus weights (amount of weights personally chosen): This exercise incorporates both trunk extension and flexion. The patient stands with the arms fully extended overhead, and then the weight is slowly moved forward and down between the legs. As the weight is between the legs the knees and hips are flexed but the back stays straight.

Russian twist plus weights (amount of weights personally chosen): The arms are extended in front of the trunk and the weight is horizontally moved from left to right in a rotating fashion or in a swinging motion from up right to down left and vice versa.

Postural Stability

Many commonly prescribed trunk muscle exercises for rehabilitation and performance may actually predispose one to injury due to the high compressive and shear loads imparted on the lumbar spine caused by excessive muscular co-contraction and extreme ranges of motion (Axler & McGill, 1997).

The exercises chosen by Lehman for stability currently have the most research supporting their ability to adequately activate the trunk musculature without exceeding cautious injury thresholds for compressive and shear loading (see below). The exercises are sufficient to adequately stress all trunk muscles responsible for maintaining a strong and stable spine. Lehman advises the performance of theses stabilizing exercises on the days that the athlete is not performing their strength exercises with the attempt to maintain a moderately neutral position while performing each exercise for 5 seconds.

Curl up: Golfer lies on back with one knee bent 90 degrees and the second leg straight. Hands should be placed under the low back to prevent spinal flexion. Golfer “curls” their shoulders 2 inches off the surface. The neck should stay in a neutral position. Strain should be experienced in the abdominal region. The golfer should focus on curling the ribcage toward their pelvis.

Bird dog: Golfer starts on hands and knees. From this 4 point kneeling position the golfer should extend one leg parallel to the floor, hold for 3 seconds and return to the starting position, repeat with the other leg. Additionally, the opposite arm can also be raised. The golfer must maintain control of the spine and minimize twisting and excessive movement.

Side support: Golfer starts in side lying position and raises their torso off the floor. Their weight should be supported by their knee and their forearm. To increase difficulty support the weight from the forearm and the golfers lateral feet.

Front support: Rolling from the side support position the golfer maintains a neutral spine and supports their weight on their forearms and the balls of both feet.
IX. METHODOLOGY

In November, 2007, after finalizing the proposed project plan, the authors met with Coach-Professor Pim Ranzijn and were advised to use the methods and structure outlined by EBP classes in the Hogeschool van Amsterdam and proposed literature to create a logical and scientific criteria list for literature grading. An original Criteria list (Appendix A) was created to higher the level of reliability of our sources. Each of the articles was researched, then read and evaluated according to the outlined criterion. A complete list of literature and grading was compiled for the creation of the Evidence Based Guideline (Appendix B). To simplify the research strategy and findings of the assessment tests, a table (Appendix C) was created to outline the specificity, sensitivity, validity, reliability and definition of each test.

Searches were performed for scientific literature related to the research objectives: Literature related to a) intervertebral disc and facet joint pathologies due to overuse injuries in Golf b) physiotherapeutic assessment of the aforementioned injuries. To guarantee a coherent research of scientific literature, the articles used for the background information of the guideline must meet a certain scientific standard. To guarantee a high standard of material, an inclusion criteria was created: writing language English, Arabic, German or French, any articles that describes the golf injuries, prevention or biomechanics concerning lumbar spine (specifically intervertebral disc and facet joint pathologies). Various databases such as Pub-med, Cochrane, Pi-carta, Cinahl, MEDLINE, Science Direct, Springer link and Pedro via a computer aided search was performed in search of published scientific literature. Digital versions of journals stated in the databases and additional manual search in journals were included. The following keywords in different combinations were used; (Golf OR Golf injuries OR Golf sport OR Golf injury prevention OR Golf rehabilitation OR golf swing biomechanics) AND (assessment OR physical examination OR physiotherapy OR physical therapy) AND (Back pain OR lower back pain OR intervertebral disc OR herniated disc OR facet joint OR lumbar spine). The sources used were categorized using the original criteria list created specifically for this document. The criteria list further categorizes the graded source into one of six levels of scientific evidence.

<table>
<thead>
<tr>
<th>Points</th>
<th>Evidence Level</th>
<th>Evidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systematic reviews</td>
<td>A*</td>
<td>Excellent</td>
</tr>
<tr>
<td>85-100</td>
<td>A</td>
<td>Very Good</td>
</tr>
<tr>
<td>70-84</td>
<td>B</td>
<td>Good</td>
</tr>
<tr>
<td>55 – 69</td>
<td>C</td>
<td>Fair</td>
</tr>
<tr>
<td>40 - 54</td>
<td>D</td>
<td>Sufficient</td>
</tr>
<tr>
<td>&lt;54</td>
<td>E</td>
<td>Insufficient</td>
</tr>
<tr>
<td>Sources other than articles</td>
<td>N/A</td>
<td>Useful / non useful</td>
</tr>
</tbody>
</table>

To the authors’ knowledge, the most relevant literature published up until the date of the completion of this study have been covered in this work. Only information gathered from literature graded “Excellent, Very Good, Good, and Fair” were included and listed while creating the guideline: Evidence Based Physiotherapeutic Guideline for the assessment and prevention of Intervertebral Disc and Facet Joint injuries in professional male golfers with Low Back Pain
X. LIMITATION OF FINDINGS & DISCUSSION

The topic at hand is so very complex and novel to the scientific world. To date, evidence based physiotherapy guidelines are rarely sport specific and lend themselves to more general physical pathologies. Sport specific physiotherapists use their vast professional experiences and knowledge when treating their patients. These experiences are rarely noted down on paper for the rest of the world to use. Much of our understanding of golf injuries relies on research conducted 10-25 years ago (McHardy, 2006). Although there are several protocols concerning the assessment of the low back and injuries available, little of these are reliable and valid. The systematic review by Hancock et al. 2007 reveals that there are relatively few studies which have investigated the diagnostic accuracy of tests to identify the disc, facet joint or SIJ as the source of low back pain. Only a few studies evaluated a cluster of signs or a combination of tests. The results of the SIJ studies found increased diagnostic validity for a cluster of tests compared to a single test in isolation, clinical practice shows that this should also pertains for disc and facet joint pathologies. Forming a diagnosis based on a combination of findings is typical of the clinical reasoning approach used by clinicians and should be further investigated in future studies (Hancock et al., 2007). Finally, linking the two (Golf and golf-specific assessment) is extremely difficult without enough relevant reliable literature.

XI. CONCLUSION

During the golf swing the spine and its structures are exposed to compression, rotational and shear forces and the facet joints are forced into their closed packed position. Injuries to the low back from the repetitive nature of the golf swing are frequent in both professional and amateur golfers (Gosheger et al., 2003). Assessment of low back pain in golfers is elaborate due to the fact that injuries are the result of a combination of factors. Namely, the repeated motions involved in the production of the golf swing along with predisposing physical dysfunctions (reduced muscular strength & flexibility, postural instability, decreased proprioception, and endurance deficits) lead to specific low back pain: Intervertebral disc and facet joint pathologies. To date, there is no scientific evidence based protocol for the assessment of low back pain in the elite level golfer with intervertebral disc or facet joint pathologies. More research is needed in this field of practice to strengthen the assessment skills of physiotherapists treating golf specific overuse injuries to the lumbar spine.
PART II. The Guideline
Physiotherapeutic Assessment & Prevention of Overuse Injuries to the Lumbar Spine resulting in Intervertebral Disc and Facet Joint Pathologies in the Elite Male Golfer: An Evidence Based Guideline

AA Naguib BSc, KJ Kersting

I. INTRODUCTION

This guideline provides information on the physiotherapeutic assessment, diagnosis and prevention of LBP in elite male golfers. The primary focus is upon professional male golfers diagnosed with Intervertebral Disc and Facet Joint pathologies caused by overuse. The aim is to delineate the origin and anatomical structures involved with these pathologies via the best available diagnostic assessment tools, to link the complex nature of the golf swing with the resulting overuse pathologies, and to finally focus on instructing golfers with safe preventative measures. It is important to note that this document is by no means a guideline of golf instruction and should not be used as such.

Over the past decade, Golf has become an increasingly popular sport with an expanding market and a growing population of participants. Likewise, the diverse population of golfers is also growing exponentially hence the amount of chronic injuries owing to overuse and swing biomechanics is a healthy amount. Unlike many sports, golf is not limited to a certain age group, with the average golfer tending to be older than athletes in other sports (approximately 25% over the age of 65, with a 50% rate of acquired golf related injuries). Even though they may have “better” swing mechanics and spend more time warming up prior to playing, professional golfers sustain more overuse injuries than amateurs. This is a result of more lengthy time spent practicing and playing the sport.

The golf swing involves a large range of motion and is repetitive, especially during practice. Combined with the large forces produced in the lower back, this may result in the increased risk of strains, disc herniation and facet arthropathy Injury to the lower back. Low back pain due to overuse is the most prevalent pathology in the elite level male golfer.

Magnitude of the problem

Inter-golfer anatomical distribution of injury is explained by their playing habits and their golf swing biomechanics. Professionals (handicap 1-9) play about 6 to 10 hours per day, while amateurs play about 3 hours +/- 1.4 days per week. Studies found that repetitive practice swings were the most common cause of injury for men (64%) and women (75%). Furthermore, the professional golfer performs more than 2000 swings in one given week. This repetitive strain on the musculoskeletal system increases the risk of acquiring an injury. There is an 89% prevalence of injury rate amongst professional golfers above the age of 50 at a rate of 1.74 per golfer. The higher injury rates, compared to non-elite golfers can be associated with the fact that they spend more time swinging and playing golf.

Low back and Golf

Low back pain is the most common complaint among all golf related injuries. Furthermore, 90% of all Professional Golf association (PGA) Tour injuries have been to the cervical and lumbar spine regions. On average, injuries to the low back cause the golfer to stop participating in his sport for 10 weeks. Swinging a golf club and playing elite level golf involves the spine to function repetitively to a great extent. The spine is involved with the transmission of forces and the coordination of activities between the upper and lower extremities. Due to the mechanics of the swing, the dorsolumbar spinal area is subject to large ranges of motion and forces acting in four directions: lateral flexion, anteroposterior traction, rotation, and compression. These four multidirectional forces are substantial during the golf swing and create damage to the lower spinal components (paraspinous muscles, intervertebral discs, vertebral ligaments, facetar joints and the posterior arc (spondylolysis)).
**Patient Characteristics & Prognostic factors**

The motivation for the professional golfer to play golf is different than that of the amateur golfer even if they share equal interest and passion for the sport. The professional male golfer is playing the sport for a living on a daily basis for more cumulative hours than the amateur golfer, who may seek to gain health benefits, exercise and energy expenditure, relaxation, and sociability from contact with the natural environment. The patient specific goal and rehabilitation expectations of a professional golfer will hence differ than those of the amateur. Depending on the amount of time spent playing Golf and at what level the patient plays (amateur or professional), different statistics prevail. 45% of amateurs and 54% of professionals complained of chronic ailments which prevented them from playing golf for an average of 5 weeks per year. Time lost from playing on the international golf tour as a result of injury averaged 9.3 weeks for men and 2.8 weeks for women. Time spent away from playing varied from one day to more than one and a half years. 10-33% of elite players will continue to play while still injured.

**Bio-psychosocial model**

There is a clear underlying cause of the pathology in the patients this document is centered around. However, the bio-psychosocial model should not be overlooked: patient specific reactions to their injury and coping strategies differ from golfer to golfer. Even though disc and facet joint pathologies are not directly due to the interaction of biological, psychological and social factors, the later two can always have an affect on the biological manifestation of the injury and cannot be clearly separated.

**Cooperation with other Disciplines**

To improve the effectiveness and efficiency of this guideline and the care provided, the physical therapist should be in close contact with the other health practitioners involved with each case. Primary care physicians, occupational therapists, psychologists, coaches, and athletic trainers involved in the specific case should come to an agreement and adopt a common policy in regard to their patient. Communication within and between the specializations is crucial to a full and efficient rehabilitation process.

**II. GOLF SWING BIOMECHANICS**

The golf swing is the process of swinging the club to hit the ball. The swing represents the phase, in which there is the greatest demand, from a biomechanical perspective, on all of the involved musculoskeletal structures. Due to its’ dynamic nature of movement, the golf swing has the potential to cause injury to the golfer. When an elite golfer performs his golf swing numerous times per day, week and month, the potential for an overuse injury is heightened and may lead him to acquire a chronic injury. Different injuries occur during different parts of the swing (table I) and frequently involve soft tissue injuries. Since injury is more likely to occur during the swing to hit the ball, it is important for the treating physiotherapist to have an understanding of the mechanics of the golf swing. This solid base will help in the understanding of the etiology of the injury and hence improve its management.

**Stages & Phases of the Golf Swing**

Through time, there have been a variety of classification schemes used to describe the phases of the golf swing. For the use of this document, the golf swing is divided into seven stages other than the Address position: The early backswing, late backswing, top of swing, downswing, impact, early follow-through, and late follow-through. The swing is also divided into four phases: the address, backswing, downswing, & follow-through.
**Table I: Phase description during the Golf Swing**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address (starting position/</td>
<td>Equal weight distribution on both feet (shoulder width apart), slight anterior flexion of the trunk at the hips (keeping the shoulders, knees and feet aligned vertically in the side view), keeping the back straight to permit easy rotation, and an extended relaxed arm position while avoiding a straight overextended, tense arm posture</td>
</tr>
<tr>
<td>pre-swing posture)</td>
<td></td>
</tr>
<tr>
<td>Backswing (From Address to top)</td>
<td>Weight shift to the right foot (for a right handed golfer) while keeping the vertebral column perpendicular to the ground in the frontal plane (upper body of the player remains leaning forward towards the ball). Simultaneous rotation to the right side around the spinal vertical axis of the knees, hips and upper limbs is executed. This raises the club to its highest point in order to obtain the widest possible arc of motion</td>
</tr>
<tr>
<td>Downswing &amp; ball impact (from top to impact)</td>
<td>Activation of an anatomical multilever system which gives the club a downswing in a rotational, angular trajectory and maximum speed which will determine the distance covered by the ball. These levers are activated in sequence from the ground level upwards; from the feet to the wrists. Weight shift to the left foot created by a linear and parallel movement of the hips and shoulders of the same side and by keeping the spine in a position perpendicular to the ground. Simultaneously the knees, hips and trunk start to rotate to the left side. Left-sided uncoiling is made possible because of the strong muscular activity of the abdominal muscles which act as trunk rotators (about 3 times the strength exerted during the back swing by the external oblique muscles) Uncoiling is possible by the paraspinal (erector spinae) muscles acting as spinal stabilizers (about 4-5 times the strength exerted during the backswing by the paraspinus muscles) and the right shoulder adductors and internal rotators (about 3-4 times and 6-7 times, respectively, the strength exerted during the backswing by the right subscapular and major pectoralis muscles). The combined effect of these actions is to bring the arms down in acceleration just prior to the ball impact. IMPACT Wrist and hands complete the acceleration of the club at ball impact by providing the ultimate push of the club head. The action is like a whip as the right hand gradually pronates during the hitting. The compressive force on the left leg and particularly on the left hip, exerted from weight transfer to the left side becomes significant (torque force of up to 300-400 pounds/inch: 8.8-11.7 kg/m²).</td>
</tr>
<tr>
<td>Follow-through (from impact to end)</td>
<td>Progressive deceleration of the club and by the rotation of the body towards the left around the axis of the spine. Superimposed and parallel left rotatory motion of both the hips and shoulders; a movement which ends when the body faces the target. Muscular activity is predominantly that of the muscles of the spine and the shoulders; - Rotator cuff muscles: supraspinatus, infraspinatus and subscapularis - Supra &amp; infraspinatus on the left side are activated mainly during follow through, while the subscapularis remains active to a similar extent to that during the forward swing and ball impact. The abdominal, dorsal, pectoral and anterior portion of the deltoid muscles are also implicated.</td>
</tr>
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The X Factor & low back pain in golfers

The golf swing has evolved over the past 50 year: The classic swing differs from the modern swing in that the spine is coiled in such a fashion for the purpose of power generation and striking distance of the ball. This is important when considering the effects on the lower back/spine and prevalence of overuse injuries to the lumbar spine. The golf swing consists of trunk rotations about three anatomical axes. The modern golf swing promotes a large shoulder turn and less parallel shoulder/hip turn about these axes. During the backswing, the upper torso rotates against restricted pelvic rotation to produce maximum angular displacement between the shoulders and hips. In the modern swing, the pelvic movement is restricted while the shoulder is turned during the backswing. This is done to promote the storing of power (elastic energy) and hence creating the maximum club head acceleration at impact,
leading to the build-up of greater torque in the back and shoulders that in turn leads to greater angular displacement which creates a greater angular club head speed/velocity in the downswing. The follow-through is characterized by a hyperextension of the back, in the reverse “C” position. The maximum difference in rotation of the hips and shoulders at the top of the backswing is called the “X-Factor”. Golfers using the modern swing have a larger X-factor, this means that the muscles of the lower, mid-section and upper body are quickly stretched before they shorten. The effective use of such golf swing strategy enables the golfer to hit the ball to greater distances. Professional golfers generally use a longer backswing amplitude (greater angular displacement) in less time than amateur golfers, increasing the velocity of the backswing and hence the rate of stretch. This larger X-factor trend during a golf swing might not be all good due to the fact that twisting may be associated with the development of back pain. The trunk rotation primarily occurs in the thoracic spine hence when the shoulders and thoracic spine rotate against the lumbar vertebrae, compression, shear and torsional stress may increase especially near the junction of the middle and lower back. If a golfer attempts to generate a maximum hip to shoulder angular displacement, beyond his physical trunk rotation limits, the excessive rotational moment on the spine may not be absorbed properly by the lumbar spine and can, over time, stress the soft tissue of the lumbar region.

**Forces, spinal loading & velocity during the golf swing**

During the golf swing, the forces applied to the lumbar spine act in four directions: compression, shear, lateral flexion, and torsion. Both amateur and professional golfers develop similar peak compression loads of over 8 times body weight, while the professional golfer was reported to attain lower levels of three other forces (shear, lateral flexion and torsion), due to better technique. The rate at which the spine is stressed and trunk muscle activity during the swing serve as a protective mechanisms for the discs.

The fast rotation velocity of the spine during the golf swing is a risk factor for injuries to the low back. As a means to amplify the speed of the club head, rather than the proper mechanics of rotating the pelvis, golfers use too much lateral weight shift of the lower body at the top of the backswing. When the lower body is shifted to one side, the spine bends laterally to the other side in order to keep the balance (see picture 1). This compensatory movement will result in difficulty for golfers to keep the anterior tilt angle of the spine that they had at address position. The golfer using this swing pattern is forced into reverse trunk inclination in the early downswing period by sliding the hips back laterally toward the target in order to hit the ball. This chain reaction forces the spine to simultaneously bend laterally toward the target in order to reestablish the original spine and torso inclination. When this violent loss and reestablishment of the spine angle takes place, the spine undergoes significant rotation and shear forces. This potential injury mechanism may be able to explain why golfers who demonstrate greater left side bending on the backswing have LBP resulting from the golf swing.

![Figure I: Lateral weight shift of the lower body, hips slide back laterally toward the target](image)
III. CAUSES & LINKS OF GOLF RELATED INJURY OF THE LOW BACK

Golf related back pain stems from mechanical, discogenic, spondylogenic pathologies or facet joint degeneration. Repetitive strain on the musculoskeletal system in professional male golfers increases the risk for an overuse injury to the spine. In short, the causes of golf injuries to the low back are primarily: overuse, technical errors, physical constraints (aerobic, muscular strength/flexibility – trunk & hip, back proprioception, postural stability), lack of warm up, and natural environment (uneven surfaces, wet conditions). The interest of this guideline focuses on the overuse injuries to the lumbar spine in elite male golfers due to its reported prevalence. It assumes that the elite golfer at hand has a biomechanically sound swing and that overuse is the main issue at hand. Over-ruling technical errors in the professional leaves us with Deficiencies other than trunk dynamics, which add to the link between swing dynamics and injuries to the low back:

Overuse

More lengthy time practicing and playing is typical of any professional top sporter. The habits of professional golfers are playing almost every day, between 6-10 hours per day to maintain or improve the quality of their game. In contrast, the amateur plays an average of 3.0 +/- 1.4 days and 14.7 +/- 7.7 hours per week. Due to the mechanics, forces placed on the spine, and complexity of the golf swing (section above), the low back is subject to large ranges of motions and forces, and the amount of time a professional golfer spends swinging places him at more risk for LBP and injury to the Lumbar spine. Other than dynamics of the trunk, factors such as aerobic deficiency, muscular imbalance (strength/flexibility), proprioception, and postural instability contribute to the relationship between the golf swing biomechanics and low back injuries.

The links:

Aerobic Deficiencies/ Cardiorespiratory Fitness
A lack of cardiovascular endurance leads to increased levels of fatigue which leads to a loss of concentration, which hence affects the shot making ability of golfers. Fatigue influences factors such as strength, speed, reaction, concentration and neuromuscular coordination. In golf, where high skill level is combined with a small margin for error, the smallest sign of fatigue can greatly affect performance.

Flexibility
Appropriate flexibility of trunk and hip muscles is suggested to decrease risks of Low Back injuries in golfers. Appropriate flexibility can decrease the resistance in the various tissues in the trunk and hip muscles and prevent the changes of normal lumbar curve caused by tight muscles. A golfer with good flexibility is less likely to injure his lumbar spine by exceeding tissue stretchability during the golf swing. More flexibility may decrease the forces applied to the lumbar spine. In order to prevent LB injuries in golfers with LBP, flexibility must be assessed.

Strength
In golf, a player needs both strength and power. We can deduce that muscular endurance is important along with this concept due to its definition: the ability of the muscle to repeatedly develop near maximal force. Strengthening the muscles involved in the golf swing is important to reduce the chance of injury and play a better game. Strengthening the muscles that support the spine is usually used as a preventative and treatment modality for patients with and without LBP. Weak trunk musculature is one of the strongest risk factors for a first time experience of LBP. Since golfers need a high-powered trunk rotation, it is indicated that research be done on golfers with and without low back pain in relation to the trunk rotation strength. Hip muscles are responsible for pelvic stability and force transmission between the lower extremities and the trunk. Imbalances in trunk and hip muscle strength may be a factor causing LBP. In athletes, the imbalance in strength between muscle groups can be caused by increases in the strength of muscles acting in opposite direction where as in non-athletes; this imbalance may be caused by weakness in one of the groups.

Proprioception and Postural Stability
Patients with LBP demonstrate difficulty in positioning and repositioning the lumbar spine or when placed in a position in the middle of the lumbar ROM. Mechanoreceptors responsible for Proprioceptive input have been found in various connective tissues, facet joints, and discs.
Furthermore, damage to even the slightest area on a facet joint may denervate the facet and this in turn may have an affect on the long term function of the spinal joint. It is important to have good proprioception for coordination of muscles and collective movements, especially when dealing with complex movements such as the golf swing for any problems in balance and coordination could alter the swing pattern of the golfer and cause extra stress to the lumbar spine.

Postural stability and balance requires coordination of many systems and muscular imbalances, or impairments can hinder postural stability. This is crucial when dealing with golfers with low back pain for if the integrity of their muscles is off, or if their balance is at stake, this may not only challenge the efficiency and accuracy of their swing, but also increases their chances of getting injured.

**IV. ASSESSMENT**

To correctly diagnose and differentiate injuries to the lower back in elite male golfers, a thorough assessment is crucial. In respect to specific low back pain especially the special tests help to clarify the differential diagnosis, as they give information about the kind of tissue causing the complaints. Being able to return or continue to play golf is crucial for professional golfers suffering from complaints of the lower back. This guideline will assist the physiotherapist in the decision making during the assessment by combining the review of literature of available assessment tools and the biomechanics of the golf swing.

The following compiled evidence of assessment tools to differentiate facet joint/ intervertebral disc involvement from general low back pain provides information with which the simple involvement of the aforementioned structures can be distinguished. Further sub classification of facet joint or disc pathologies is beyond this work.

**Anamnesis (Gathering of information)**

**Red flags**
- Presenting age < 20 years or onset > 55 years
- Violent trauma, such as fall from a height, car accident
- Constant, progressive non mechanical pain
- Pain unaffected by position or medication
- Severe night pain
- Severe spasm
- Thoracic pain
- Previous history of carcinoma, systematic steroids, drug abuse, HIV
- Systematic unwell feeling / weight loss
- Persisting severe restriction of lumbar flexion
- Structural deformity
- Investigations when required: sedimentation rate (ESR) > 25, plain x-ray: vertebral collapse or bone destruction

**Yellow flags**
- Nerve root pain or specific spinal pathology
- Reported severity of pain at the acute stage
- Beliefs about pain being work related
- Psychological distress
- Psychosocial aspects of work
- Compensation
- Time off work

**Referral**

This document is concerned only with the management of chronic overuse injuries (over three months duration) associated with two specific pathologies in elite golfers: Intervertebral Disc and Facet joint pathologies in the Lumbar spine. This guideline is a tool to be used only in conjunction with a physician referral and diagnostic imaging of the injury site: Lumbar disc or Facet Joint pathology. The physiotherapist is to work in close contact with the referring physician so as to optimize benefits of this guideline.

**Standardization of testing for better value**

To evaluate reliability of clinical tests, it is important to make sure the tests are performed in exactly the same way by the examiners and that the limit of normality is defined. Many clinical tests, even if they have the same name, are performed and evaluated differently. It is important that clinical tests do not get rejected because of low reliability that is caused by a lack of standardization of technique or of evaluation of test results. It is important that experienced therapists develop standardized structures in their performance and evaluation of clinical tests.
**General Information**
- Age?
- disc problems occur between 15 – 40 years
- ankylosing spondylitis 18 – 40 years
- osteoarthritis of the facet joints and spondylitis mostly evident in patients older than 45 years

if a disc herniation is responsible for the back pain, the patient can recall the distinct time of onset, by experiencing sharp, burning, stabbing pain radiating down the leg and below the knee on the posterior or lateral aspect, whereas if the pain is of gradual onset, other degenerative diseases are more probable than disc herniation.

**Pain** (Questions to be asked after filling out the Oswestry Questionnaire) see appendix D

**Time of onset: distinct time/gradual?**
Discogenic pain can be further characterised by being superficial and local, and it is often associated with numbness or tingling. In the more severe cases, motor deficit, diminished reflexes or weakness may occur.

**Superficial & local/ deep & general?**

**Pain upon active movements:**

**During standing and twisting motions?**

- low back strain

**Gets worse in positions like sitting?**

(produce increased pressure on the annular fibers) low back pain and saddle pain in the S1 and S2 distributions. Pressure on the intervertebral disc is increased during sitting and bending postures, as opposed to standing or recumbent positions

**Central disc herniation (relatively uncommon)**

**pain on coughing and sneezing?**

Disc pathology (is considered as a reliable sign, increases pressure on L3 up to 35 %: care with the interpretation of this clinical sign must be given and no single conclusion should be drawn. Answers concerning the decrease and increase of pain in certain positions give information about the underlying cause)

**Increases as a position is maintained for a longer time?**

**Disc pathology**

- Constant pain during repetitive movements and morning stiffness but improvement through activity?
- Facet joint degeneration

**Difficulty in urination, incontinence or impotence?**

A central herniated disc may also compress nerve roots of the cauda equina

**Which part of the golf swing exacerbates the pain?** (to be noted initially then analysed in the functional assessment section to follow)
Table II: Injuries Associated with the Spine at Each Phase

<table>
<thead>
<tr>
<th>Phase</th>
<th>Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>From Address to end of Backswing</td>
<td>Upper body anterior flexion at dorso-lumbar spine instead of at hips increases risk of</td>
</tr>
<tr>
<td></td>
<td>hypermobility of vertebra and abnormal muscular tension during the backswing.</td>
</tr>
<tr>
<td></td>
<td>- Too wide a stance increases the tension on the spine and reduces the ease of trunk</td>
</tr>
<tr>
<td></td>
<td>rotation</td>
</tr>
<tr>
<td></td>
<td>- An overly long backswing may cause a rotational trunk injury or may throw the</td>
</tr>
<tr>
<td></td>
<td>player off balance leading to ground impact injuries.</td>
</tr>
<tr>
<td></td>
<td>- Leftward spinal tilt, instead of being perpendicular to the ground, during the</td>
</tr>
<tr>
<td></td>
<td>rightward shift increases the chance of an opposite spinal curve (reverse C) posture at</td>
</tr>
<tr>
<td></td>
<td>the end of the follow through.</td>
</tr>
<tr>
<td>From Forward swing and acceleration</td>
<td>Thoracic and abdominal muscular strains can occur after vigorous trunk rotation on the</td>
</tr>
<tr>
<td>to impact</td>
<td>downswing</td>
</tr>
<tr>
<td>From Early Follow through to late</td>
<td>Injury to the hips or dorsolumbar spine can occur if the deceleration of the follow</td>
</tr>
<tr>
<td>follow through</td>
<td>through is too brisk/aggressive.</td>
</tr>
<tr>
<td></td>
<td>- An overly powerful drive, including a reversed “C” lordotic spinal curvature, can</td>
</tr>
<tr>
<td></td>
<td>induce abnormally high stresses on the dorsolumbar vertebral bodies, especially on the</td>
</tr>
<tr>
<td></td>
<td>posterior joint</td>
</tr>
</tbody>
</table>

* The most difficult aspect of evaluating patients with symptoms of a central herniated disc is differentiation between low back strain and herniated disc

**Physical examination**

**Active range of motion (ROM)**

Sufficient active range of motion of the lumbar spine and the hip is essential during the golf swing as it requires the spine to simultaneous flex, extend and rotate to great degrees.

- Note painful movements and limitations which occur.
- Good inter-rater reliability for lumbar flexion, extension and lateral flexion in patients suffering from degenerative lumbar conditions.
- An increase of pain during lateral flexion to the painful side plus radiculation into the leg suspects a herniation of the intervertebral disc.
- In case radiculation are absent the increase of pain may predict the involvement of the lumbar facet joints.
- The increase of pain during lateral flexion to the pain free side may predict a protrusion on the medial side of the nerve root, articular or muscular cause.
- Pain during extension and rotation, has to be examined with great attention and care as these are the typical movements of the golf swing and the closed packed position of the facet joints. Positive signs indicate facet syndrome.
- Further in case the facet joints are the underlying cause of the complaints than low back stiffness, the absence of radiculation and neurological deficits, no hip or buttock pain, leg pain only above knee and the absence of paresthesia should all be results of the examination.
- Golfers with low back pain show reduced lumbar extension and flexibility deficits in the hip internal rotation and Faber's distance of the lead leg.
- Trunk rotation during the golf swing in golfers with LBP exceeds their maximum voluntary trunk rotation in neutral posture.
- Reduced trunk rotation angle caused by decreased pain during lumbar flexion suggests discogenic pain flexibility.
- Pain on lumbar extension suggests facet disease.
- Disc herniations had significantly less range of movement during forward bending in standing and higher pain distribution in the leg during backward bending in standing, strong predictor.

**Proprioception / Postural stability**

The clinical assessment of joint position sense can be difficult and its validity has been questioned while the cost of sophisticated balance systems may limit access for many practitioners.
One common clinical approach to the measurement of proprioception and static stability is that of single leg stance tests (SLST), also referred to as the Romberg test, where the patient is required to maintain balance while standing on one leg for 20 seconds.

The Star Excursion Balance Test (SEBT) as a validated measure of dynamic balance ability which, unlike force plates or electronically controlled balance platforms, is a simple and highly portable test that could be employed in a range of clinical environments.

Passive Range of Motion
Passive movements are difficult to perform due to the weight of the body and difficulty isolating the lumbar spine from the surrounding joints. Therefore the assessment of the end feel is advised during joint play assessment of the individual vertebrae of the lumbar spine, as it is safer.

Muscle testing
The abdominal muscles are active considerably during the golf swing and are active in the acceleration phase to generate power (Horton et al., 2001). Considering the contributions of the trunk muscles in rotation and lateral bending movements and the repetitive nature of the game of golf, it is possible that muscular fatigue could develop during game or practice (Horton et al., 2001). The relationship between muscle deficiency and chronic low back pain (CLBP) is not clearly understood, especially in golfers, however it is known a lack of strength and endurance of the trunk muscles appears to be a significant risk factor in the development and occurrence of CLBP.

Extending from the pelvis and sacrum upwards to the base of the skull, the Erector spinae is the main spinal muscle which is involved in spinal extension and stabilization. Included in the spinal muscle group is the Multifidus muscle which mainly prevents spinal rotation and helps protect the spine from rotational forces creating the torque (like the torque created during the golf swing).

Table III: Function of the abdominal muscles in spinal motion during the golf swing

<table>
<thead>
<tr>
<th>Abdominal muscles **</th>
<th>Function in the golf swing</th>
</tr>
</thead>
</table>
| Rectus Abdominus     | - Flexion of lumbar and thoracic spine during address  
|                      | - One side works alone: lateral flexion of the spine, especially during the backswing and the forward swing  
|                      | - Lower portion → shows more activity during the take away and the late follow through phases  
|                      | - Upper portion → shows more activity during the progression of the swing  
|                      | - overall reached its peak activity during the acceleration phase  
|                      | - Involved during all phases of the golf swing |
| Obliques Externus Abdominus | - Flexion of the lumbar and thoracic spine, during address  
|                       | - Lateral flexion of the spine during the backswing and the forward swing  
|                       | - “Rotation” of the spine helping to store kinetic energy for the acceleration through the ball at impact  
|                       | - Involved in all phases of the golf swing, highest activity shown during the take-away and follow-through phases  
|                       | - Decelerates the trunk during the follow through phase |
| Obliques Internus Abdominus | - Flexion of the lumbar and thoracic spine as the golfer sets up for the shot  
|                      | - Lateral flexion of the spine  
|                      | - Rotation of the spine  
|                      | - Involved in all phases of the swing, highest activity shown during the take-away and follow through phases  
|                      | - Decelerates the trunk during the follow through phase |
| Transversus Abdominus | - Plays no role in moving the spine  
|                      | - Actively involved in all phases of the golf swing, helping to stabilize the spine during the rotational motion of the swing  
|                      | - Forms an integral part of the core muscles |
| Combination of all 4 muscles | - Overall the muscles have low activity during the take away phase (back swing) with the highest activity during the forward swing and impact phases  
|                  | - Provides the stabilization golfer needs to stay “down” during impact and follow through. |
The selection of muscle strength testing should be based on the function of muscle performance during the tasks, such as maintaining the joint stability, posture, or the dynamics of motion.

The modern golf swing restricts the hip turn to build torque in the back and shoulders during the backswing for maximum club head velocity at ball impact.

Hip muscles play an important role in stabilizing the movement of the pelvis during the golf swing.

Trunk muscles are responsible for rapid torso rotation, flexion, extension, and side bending in one combined movement.

Measurement of isometric hip muscle strength and isokinetic trunk muscle strength is appropriate for assessing the strength differences between golfers with and without LBP.

Rapid motion is able to discern the loss of muscle function in patients with LBP better than slow motion.

Isokinetic test at slow speeds, considered to reveal articular problems.

Evaluation of trunk strength at both fast and slow speed provides more information regarding back problems in golfers with LBP as compared with their healthy counterparts.

- Dynamic abdominal endurance test
- Double straight leg lowering
- Internal/external oblique test
- Dynamic horizontal side support test
- Dynamic extensor endurance test
- Isometric extensor test
- Back rotator/multifidus test

Among the great variety of muscle strength and endurance tests, only evidence about the following is available:

Isometric extensor endurance test

<table>
<thead>
<tr>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/B/A</td>
</tr>
</tbody>
</table>

Grades indicate the strength of the evidence, rather than the importance of the recommendations—see method section

- The prone isometric chest raise test (high reliability in the testing of healthy and LBP patients and a moderate test re-test reliability; validity no valuable conclusion drawn).
- The Biering-Sorensen test of trunk extensor endurance (high reliability between trials and satisfactory intra-observer reproducibility in healthy and LBP individuals & high sensitivity in between individuals) A global measure for the back extension endurance capacity.
- The easily fatigued rectus abdominis/internal oblique indicating level of muscle fatigue.
- The rectus abdominis and internal oblique co-activity may stiffen the spine to reduce small-amplitude high-frequency perturbations or large amplitude movements across multiple segments.
- The activation of the superficial abdominal muscles provide stability at the expense of the back extension performance.
- Individuals with LBP have an increased level of co-activation and fatigue faster than normal or have less co-activation and present with a poor performance due to poor extension muscle capacity.
- High reliability of Biering–Sorensen test only in the assessment of LBP
- The hip extensors, superficial and deep abdominal muscles influence the test

Tight hip extensors and hamstrings may decrease lumbar lordosis and tight hip flexor may increase lumbar lordosis. Special attention to the flexibility state of the muscles around the pelvis should be given. If the patient is not able to maintain a neutral position of the pelvis due to muscle imbalance, the erector spinae, hamstrings and iliopsoas being tight while the abdominal and gluteal muscles are weak and lengthened, a pelvic crossed syndrome is present.

Functional assessment

Use Qualitative Golf Kinematics with the aim of: observing a golf skill being performed, evaluating its effectiveness, and giving appropriate feedback to the golfer. *Rememer that this is not a golf instructional manual, the main goal of the functional assessment part of your assessment is to breakdown the movements which are used repetitively (the swing) and relate them to the skeletonmuscular dysfunctions that present themselves within the rest of your assessment.

How:

Break up the swing into stages & phases:

Apart from the Address position, the golf swing is divided into seven stages: The early backswing, late
backswing, top of swing, downswing, impact, early follow-through, and late follow-through. The swing is also divided into four phases: the address, backswing, downswing, & follow-through.

The key elements in each phase of the swinging movement must refer to specific body movements and must be observable. The observation plan should be indicated: from which angle will the swing be observed? What parts of the body will be examined? And how many times will the skill be performed for evaluation? The patient should be observed in an environment mimicking as closely as possible the competitive environment which the athlete takes part in.

**Analyze key elements involved:** therapist can use his/her theoretical model of how the skill should be performed based on mechanical principles (detailed above in the golf swing biomechanics section & Review) in combination with the observed skill to evaluate the problem.

**Observe a golf skill being performed:** Evaluate its effectiveness and give appropriate feedback to the golfer:

- Ask the golfer to mimic his swing a couple of times (if possible record this on video tape for future evaluation)
- Ask the golfer to use his own club while performing the movement
- Ask about pain: which part of the swing exacerbates the pain?
- Golfer should be dressed as he would normally dress for a round of golf

*It is imperative to note down your findings so as not reduce evaluation mistakes and confusion during future evaluation*

**Patient’s swing is compared with the theoretical desired swing:** use knowledge of swing mechanics to compare your patients swing to the desired swing.

You may use stage or phase description tables provided in this document.
Table IV: Description of Stages during the Golf Swing

<table>
<thead>
<tr>
<th>STAGE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address (Set-up)</td>
<td>Position of body just prior to initiating the golf swing: Feet are shoulder or hip width apart, knees slightly flexed (20-25 °), trunk flexed (45 °) at the hips, posterior pelvic tilt, arms relaxed hanging down from shoulders, right shoulder slightly elevated(right lateral shoulder tilt 16 ° (result of right lateral bending in the spine and slight depression and downward rotation of right arm and scapula – right hand is lower on the club than left hand), hands and wrists are activated griping onto the club. 50-60% of golfer’s weight is on the back foot.</td>
</tr>
<tr>
<td>The early backswing (BS),</td>
<td>The body begins to move, rotating the trunk and arm upwards away from the target, purpose being to position golfer’s GOC and club head so as to execute a correct &amp; powerful downswing, to stretch the musculature and joint structures responsible for generating power in the downswing. Shoulders rotate and pull hips into a rotated position while the arms move upward.</td>
</tr>
<tr>
<td>Late Back Swing (BS)</td>
<td>Rotation continues, bringing the club further away from the starting position.</td>
</tr>
<tr>
<td>Top of Swing (Top)</td>
<td>Transition point from back to downswing: elbows are level, shoulders turned two times as much as the hips and hands are away from the body. Right arm is abducted (75-90 °) and externally rotated (90 °). Left elbow is extended, left shoulder is internally rotated and horizontally adducted across the chest. Left scapula is abducted, elevated and outwardly rotated, and the wrist and hands are cocked. The left posterior rotator cuff muscles are stretched and the GH joint is in an impingement position. Left leg bears about 40% of the bodyweight and is passively externally rotated because of the right pelvic rotation. If patient has limited hip external rotation or tibia internal rotation, the heel leaves the ground (may cause stress on the left leg). If the patient has limited hip internal rotation, the feet can be abducted 10-20 ° in compensation.</td>
</tr>
<tr>
<td><strong>Downswing (DS)</strong></td>
<td>With little leg movement, the arms begin to drop down (release) while the elbows are still level in the first half of this stage. Purpose of the DS is to bring the club head to the ball in the correct plane with maximum velocity (on average it takes an elite golfer 0.23 seconds to perform this). Left pelvic rotation (begins before arms have completed the backswing) The left arm externally rotates and moves toward the midline, the right arm internally rotates and adducts and the elbow extends.</td>
</tr>
<tr>
<td><strong>Impact</strong></td>
<td>Once again, the club, shaft and hands are in line with the player’s belt buckle. This is a mirroring of the address stage in which the spine and back of the head are aligned. Likewise, the shaft angle is the same as at address (club face points in the same direction as the back of the left hand at the target. Shoulder rotation is about 27° and hip rotation about 43° to the left.</td>
</tr>
<tr>
<td><strong>Early follow-through</strong></td>
<td>Extension of down swing and impact positions. The club and trunk rotate towards the target. The arms swing past the left leg (front leg for right handed players), as club is slung through the ball and up to the top. Deceleration of the body and club head by using eccentric muscle activity. Hands and wrists follow the plane of the swing path. Left shoulder and arm further abduct and externally rotate, right shoulder and arm adduct and internally rotate.</td>
</tr>
<tr>
<td><strong>Late Follow-through</strong></td>
<td>When the golfer’s hands reach the shoulder level and both elbows flex to slow down the arm and trunk rotation speed while keeping postural stability. Trunk and hip rotation continues to the left, left leg internally rotates (weight absorbing), left ankle supinates. Golfer finishes in a balanced position with the trunk facing the target in slight hyperextension and lateral flexion. Hands behind left ear and head rotated to the left.</td>
</tr>
</tbody>
</table>
Other points of reference while analysing the swing:

Blanchard’s 3 key points of identification in the patients’ golf swing:

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Expert advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is the position of the back foot perpendicular to the plane line? (to ensure a directional release of energy directly toward the intended target; the open back foot permits over-rotation of the lumbosacral spine.)</td>
<td></td>
</tr>
<tr>
<td>2. Does the extended forward arm trace parallel to the plane line during the backswing and the downswing? (When a golfer swings safely, the kinetic energy is released directly toward the intended target. Because the Plane Line is continuous with the target line, it should make sense that the forward arm should sweep parallel to the Plane Line to release the energy of the body directly toward the target).</td>
<td></td>
</tr>
<tr>
<td>3. Does the club shaft point the plane line throughout the swing? (With this position, the golfer can coil and then release his stored kinetic energy directly toward the intended target).</td>
<td></td>
</tr>
</tbody>
</table>

Blanchard’s 14-point flexibility examination: (below are the points relating to the L-spine assessment)

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Expert advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>“The Cannonbal”: assesses basic spinal flexion (patient is seated at the edge of a chair and asked to tuck their chin to the chest and wrap the arms around the knees and hold for 1 minute).</td>
<td></td>
</tr>
<tr>
<td>“Toe touch”: hamstring flexibility (ask patient to bend over and reach to touch the toes and hold for 1 minute)</td>
<td></td>
</tr>
<tr>
<td>Side flexion (bilateral stretch held for 1 minute): patient stands with the palm of their hands to their sides and is asked to slide their hands down the side of their thigh until the fingertips reach the knee without rotation of the torso. If the patient cannot bend laterally, their torso will move up and down while swinging the club and jeopardize their ability to keep their extended left arm parallel to the plane line when swinging the club.</td>
<td></td>
</tr>
<tr>
<td>Rotation: making sure rotation is equally bilateral for if not, patients are more prone to injury.</td>
<td></td>
</tr>
<tr>
<td>Extension (hold for 1 minute): using a Swiss ball, the patient lies down in extension with their head in contact with the ball, knees flexed at 90 degrees and heels on the ground with no pain. Extension of the lumbar and thoracic spine is needed to keep the club shaft “on plane” after impact with the ball, and extension of the entire spine is necessary to hold the finish position.</td>
<td></td>
</tr>
</tbody>
</table>

The Oswestry Disability Questionnaire (appendix D)

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional capacities and patient’s ability to function outside of golf. This disability index is calculated by dividing the total score by the number of sections answered and multiplied by 100.</td>
<td></td>
</tr>
</tbody>
</table>

so that their assessment is based on sound mechanical principles and not subjective judgements of skill level.
**Functional Assessment conclusion**

Use the gathered functional information while continuing with your assessment, keeping the patients primary realistic goal in mind.

*If quantitative Golf Kinematics is required (to provide numerical data on the internal and external forces during golf movements), please refer your patient to the appropriate specialist.*

**Special Tests**

The following list of special tests is by no means a full and complete list of all available tests. The tests described below are those which the authors found to be most efficient, practical and which were evaluated by evidence based means, hence serve the purpose of the guideline to follow.

- Special tests are considered an integral part of the large examination process, should never be executed in isolation because these tests depend on the personal skills of the examiner.
- The straight leg rising test, the prone knee bending test and slump test should always be done especially in case of neurological symptoms.
- Therapists to develop skills in 2-3 tests effectively and widen the understanding of how neurological tissue is being stretched and which neurological tissue in particular is demonstrating signs and symptoms.
- Importantly the reliability outcome depends on the kind of scale used for statistical analysis and interpretation.

**Straight leg raising/ Lasegue test**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>A*/B/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>This test evaluates the mechanical movement of the neurological tissue and tests the sensitivity to mechanical stress or compression.</td>
<td></td>
</tr>
<tr>
<td>Low specificity but a high sensitivity, satisfactory reliability between raters</td>
<td></td>
</tr>
<tr>
<td>The most appropriate test for the lower lumbar nerve roots</td>
<td></td>
</tr>
<tr>
<td>Moderately accurate</td>
<td></td>
</tr>
</tbody>
</table>

**The active straight leg raising**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid and reliable although unclear for which population</td>
<td></td>
</tr>
</tbody>
</table>

**Crossed straight leg raising**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>A*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproduction of specific but intense pain</td>
<td></td>
</tr>
<tr>
<td>High specificity but low sensitivity.</td>
<td></td>
</tr>
</tbody>
</table>

**Slump test**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>A/D</th>
</tr>
</thead>
<tbody>
<tr>
<td>The slump test evaluates the movement and mechanical properties of neurological tissue.</td>
<td></td>
</tr>
<tr>
<td>Moderate specificity but high sensitivity</td>
<td></td>
</tr>
<tr>
<td>Executed with a great deal of careful, sensitive handling and interpretive skills</td>
<td></td>
</tr>
<tr>
<td>General reliability of this test as low but inter-rater reliability high</td>
<td></td>
</tr>
<tr>
<td>Pain distribution during test: patients with disc herniation tend to have more pain in the leg during slump test compared with the patients with bulging discs/ patients without positive findings (no significance)</td>
<td></td>
</tr>
</tbody>
</table>

**Quadrant test**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>B/B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination of active movements assessing for facet joint dysfunction in the lumbar spine</td>
<td></td>
</tr>
<tr>
<td>High predictor of symptom severity and the most common test to reproduce the patients’ symptoms, as it points out those subjects with clinically meaningful low back pain symptoms</td>
<td></td>
</tr>
<tr>
<td>No prediction of impaired function</td>
<td></td>
</tr>
<tr>
<td>High inter-rater reliability of the quadrant test</td>
<td></td>
</tr>
</tbody>
</table>
Schöber test / modified- modified Schöber test

**Recommendations**

<table>
<thead>
<tr>
<th>A*/A/A</th>
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<tr>
<td></td>
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</tbody>
</table>

- Measurement of the sagittal lumbar spine range of motion in centimeters
  - high intrarater and interrater reliability
- Modified- modified Schober test
  - moderate validity but an excellent reliability
  - No proof that the test is not valid

**Hip extension test**

**Recommendations**

<table>
<thead>
<tr>
<th>B</th>
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</table>

Two tests available using hip extension to evaluate motor control of the lumbar spine and secondly testing the femoral nerve.

- Femoral stretch test as an evaluation tool for the reproducibility of pain, the patient lies in either the prone or the lateral decubitus position. The thigh is extended at the hip, and the knee is flexed. Reproduction of pain suggests upper nerve root (L2, L3 and L4) disorders.
- Test for suspecting impaired motor control of the lumbar spine through deviation of the lumbar spine from the neutral position during the raising of the leg. This typically took 1 of 3 forms: (1) rotation of the lumbar spine such that the spinous processes appeared to move toward the side of hip extension; (2) lateral shift of the lumbar spine toward the side of hip extension; or (3) extension of the lumbar spine. Co-contraction of deep segmental stabilizing (primarily transverse abdominis/multifidis) muscles decreases lumbar deviation or does the superimposition the contraction of the larger stabilizing muscles of the trunk (erector spinae, rectus abdominis, and external oblique) on the contraction of the deeper muscles would usually bring about reduced deviation
- the deviation of the lumbar spine that often occurs during the hip extension test represents inability of the stabilizing system of the spine to properly perform its function in automatically ordering co-contraction of the stabilizing muscles in response to perturbation, here in the form of the raising of the leg
  - good inter-examiner reliability in detecting deviation of the lumbar spine from the midline, as well as validity in regard to the tests ability to distinguish patients with chronic low back pain from normal individual.

Revel's criteria

**Recommendations**

<table>
<thead>
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</tbody>
</table>

This test is a combination of standing flexion, returning from standing flexion, standing extension and finally extension and rotation

- Low sensitivity and high specificity
- Test is unsuitable as a clinical screening test to evaluate chronic low back pain
- Currently available tests have limited or no diagnostic validity
- No advice in the practical use of this test can be given

McKenzie / lumber extension test

**Recommendations**

<table>
<thead>
<tr>
<th>A</th>
<th></th>
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</thead>
<tbody>
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</tbody>
</table>

Clinical sign to evaluate and treat patients with acute herniated nucleus pulposus

- 94% of the patients who were unable to reach normal lumbar extension, disc hernia was found at operation.
- no significant differences in identifying patients with disc herniation

McKenzie side glide test in standing, an increase in the neurological symptoms is provoked due to a prospected involvement of the intervertebral disc.

- no information concerning reliability and validity
Reflex testing

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing the achilles / patellar reflex, symptoms do not always provide a clear diagnosis of the level.</td>
<td></td>
</tr>
<tr>
<td>The absence of an achilles reflex is more indicative of disc prolapse than impairment of this reflex</td>
<td></td>
</tr>
<tr>
<td>no significant noticed for muscle weakness, sensory impairments or reflex depressions.</td>
<td></td>
</tr>
</tbody>
</table>

V. PREVENTION

The available scientific literature suggests different types of exercise types to prevent golf related lower back injuries: warm up, strength, flexibility and cardiovascular exercises. Lower back pain as a result of a golf swing often arises from two different sources: (a) overuse of muscles in the trunk and (b) poor physical condition of these muscles. Good physical conditioning permits reasonably prolonged golf practice each week throughout the year without harm, and helps to prevent overuse injuries in particular.

* Patient should be given Golf Specific prevention protocol (Appendix F), along with sound instructions and demonstrations of each exercise

Warm Up

The physiological reasons for warm up exercises include the increase in body and muscle temperature which cause an increase in enzyme activity and thus the metabolic reactions associated with the energy systems, the increase in blood flow and oxygen availability, and decrease in contraction and reflex time.

An appropriate warm up for golfers should include a period of aerobic exercise, followed by stretching of the “golf muscles” (hands, wrists, forearms, shoulders, lower back, chest, trunk, hamstrings, and groin). A series of golf swings with a progressive increase in range of motion and vigor should then be performed, progressively starting with the short clubs going over to the longer ones. Warm up also increases golf performance and club head velocity.

- Calisthenics such as jumping jacks and easy running, walking, cycling for 5 to 15 minutes prior to swinging a golf club.
- Pelvic twist for proper alignment and unrestricted movements are important for balance and power, 5-10 times on each side. Patient places feet straight ahead and directly under his hips. He is to holds the shaft of his driver against the small of his lower back, palms facing forward. He then tilts his spine slightly forward from the waist. As he slowly rotates to the left and right, he keeps his weight on the inside of his feet. The forward curve in his lower back should be maintained.

Cardio-Respiratory Fitness

An increase in the level of cardio-respiratory fitness will enable the golfer to complete a round of golf feeling less exhausted and thus better able to continue to execute the many golfing skills to prevent fatigue cardio-vascular exercises such as cycling, jogging and brisk walking 3-4 times a week 30-40min which will build up aerobic/ cardio-vascular / respiratory endurance, and to assist with weight control.

Flexibility

Golfers need a good range of motion of the lumber spine, flexibility of the trunk and hip musculature, spinal rotation and shoulder mobility to successfully execute the golf swing. Appropriate flexibility can decrease the resistance in various tissues in the trunk and hip muscles and prevent the changes of normal lumbar curvature caused by tight muscles and the risk of injury.

Following stretches are to be executed prior to a round of golf (3-4 times per week), as prevention for golf related back injuries:

- Cat stretch
- Knee to chest sequence
- Prayer stretch
- Spinal rot
- Hamstring stretch

* Holding time of each stretch is 20-30 seconds, repeated 2-3 times. The stretches are performed in a slow, controlled manner, with no pain and natural breathing pattern → for detailed description see Flexibility Part I
The aim of a golf exercise program is to improve the endurance and strength of trunk muscles to further facilitate their ability to stabilize the spine in neutral and non-neutral positions and improve their ability to produce force during the golf swing and reduce the risk of injury.

- Cable punch
- Lawnmower Pull
- Weighted golf swing
- Reverse scaption
- Medicine ball toss
- Deadlift

Following strengthening exercises can be easily performed with less equipment at home:

- Prone isometric abs
- Quadraped arm opposite leg raise
- Floor two leg bridge
- Floor prone cobra
- Ball bridge
- Scapular retraction
- Wood chopper plus weights (amount of weights personally chosen):
  - Russian twist plus weights (amount of weights personally chosen)

*These strengthening exercises are golf specific but require a gym and equipment. For detailed description see Strength Part I*

Postural Stability

The exercises for stability currently have the most research supporting their ability to adequately activate the trunk musculature without exceeding cautious injury thresholds for compressive and shear loading (see below). The exercises are sufficient to adequately stress all trunk muscles responsible for maintaining a strong and stable spine. The performance of these stabilizing exercises on the days that the athlete is not performing their strength exercises with the attempt to maintain a moderately neutral position while performing each exercise for 5 seconds.

- Curl up
- Bird dog

VI. CONCLUSION

During the golf swing the spine and its structures are exposed to compression, rotational and shear forces and the facet joints are forced into their closed packed position. Injuries to the low back from the repetitive nature of the golf swing are frequent in both professional and amateur golfers. Assessment of low back pain in golfers is elaborate due to the fact that injuries are the result of a combination of factors. Namely, the repeated motions involved in the production of the golf swing along with predisposing physical dysfunctions (reduced muscular strength & flexibility, postural instability, decreased proprioception, and endurance deficits) lead to specific low back pain: Intervertebral disc and facet joint pathologies. To date, there is no scientific evidence based protocol for the assessment of low back pain in the elite level golfer with intervertebral disc or facet joint pathologies.

With an ever growing number of participants in the game of Golf, sooner or later you will encounter your first golf injury patient, and given the statistics, he will most likely present with LBP and related pathologies. It is only with experience and repetition of tests that you will become comfortable enough in correctly diagnosing and treating such ailments. Even though the sport of golf lags behind other sports in the available evidence based literature for physiotherapeutic use, this will in time change and more such guidelines will be available for professional and scholarly use.
PART III: The proposed article “product” for Golf in Egypt

Physiotherapy & Golf: Prevention of Low Back Pain

From a Physiotherapy standpoint, it is only logical to deduce that the game of golf was invented by someone whom wanted to cause harm to the human spine. That being said, over the past decade, golf has become an increasingly popular sport with an expanding market and an exponentially growing population of participants. Furthermore, the amount of chronic injuries owing to overuse and swing biomechanics is a healthy amount.

Unlike many sports, golf is not limited to a certain age group, with the average golfer tending to be older than athletes in other sports (approximately 25% over the age of 65, with a 50% rate of acquired golf related injuries). Even though they may have “better” swing mechanics and spend more time warming up prior to playing, professional golfers sustain more overuse injuries than amateurs. This is a result of more lengthy time spent practicing and playing the sport. The golf swing involves a large range of motion and is repetitive, especially during practice. There is an 89% prevalence of injury amongst professional golfers above the age of 50 at a rate of 1.74 per golfer. The higher injury rates, compared to non-elite golfers can be associated with the fact that they spend more time swinging and playing golf.

The site upon which a golfer sustains an injury is explained by his/her playing habits and their golf swing biomechanics. Professionals (handicap 1-9) play about 6 to 10 hours per day on a daily basis, while amateurs play about 3 hours +/- 1.4 days per week. Studies found that repetitive practice swings were the most common cause of injury for men (64%) and women (75%). Furthermore, the professional golfer performs more than 2000 swings in one given week, hence this repetitive strain on the musculoskeletal system increases the risk of acquiring an injury.

The golf swing, combined with the large forces produced in the lower back may result in an increased risk of medical problems to the low back such as muscular strains, disc herniations and facet arthropathy. Low back pain is the most common complaint among all golf related injuries. On average, injuries to the low back cause the golfer to stop participating in his sport for 10 weeks.

Swinging a golf club involves the spine to function repetitively to a great extent. In order to understand the concepts presented in this article, it is important to have a basic understanding of the parts of the body involved in relation to the low back and golf. The vertebral column has been classically divided into several distinct parts: the cervical spine, the thoracic spine, the lumbar spine and the sacral spine. The hips and pelvis provide a foundation for the spine to sit upon. The spine is made up of 33 bones called vertebrae (7 cervical, 12 thoracic, 5 lumbar, and 5 sacral vertebrae) which interact with the arms and legs to allow for proper movement.

![Figure IV: Spinal Anatomy](image-url)
The spine is involved with the transmission of forces and the coordination of activities between the upper and lower body. Due to the mechanics of the golf swing, the low back (lumbar spine) is subject to large ranges of motion and multidirectional forces. Other than the vertebrae, various structures help move the spine in functional activities. The joints connecting one vertebra to the other in the low back are the facet and intervertebral joints. The facet joints allow you to bend forward, backward, bend side to side, and rotate on a non moving base. The intervertebral joint consists of an intervertebral disc which functions to bear and distribute loads, restrain excessive movements, and to allow slight motions. Along with the bony vertebrae and joint structures, the surrounding muscles and ligaments stabilize the spine. It is crucial for a golfer to understand that these forces imposed on the spine can cause damage the lower back.

Repeated stress on the spine caused by the golf swing can cause muscles to tire easily and lead the golfer to the use of a preferred muscle over another (compensation) causing a muscular imbalance (strength/flexibility impairments). Lower back pain as a result of a golf swing often arises from two different sources: (a) overuse of muscles in the trunk and (b) poor physical condition of these muscles, both possibly leading to more serious complications such as intervertebral disc and facet joint pathologies. Good physical conditioning permits reasonably prolonged golf practice each week throughout the year without harm, and helps to prevent overuse injuries in particular. Preventative measures must be taken by golfers of all ages and skill levels to reduce the risk of acquiring a potentially chronic injury to the low back.

Playing 18 holes of golf or spending hours on the driving range under the burning heat of the sun is not the only way to train for golf. Believe it or not, much can be done in the comfort of a home or office. The available scientific literature suggests different types of exercises types to prevent golf related lower back injuries: warm up, strength, flexibility and cardiovascular exercises.

**Warm Up**

The purpose of a warm up is to prepare the body both physiologically and psychologically, while at the same time reducing the risk of injury. Literature agrees upon the belief that a properly conducted warm up procedure reduces the chance of injury during golf, however, as the benefits of golf warm up procedures have not been formally studied, the current recommendations for such activities are inconsistent. What is clearly known are the physiological reasons for warm up exercises, which include the increase in body and muscle temperature which cause an increase in enzyme activity and thus the metabolic reactions associated with the energy systems, the increase in blood flow and oxygen availability, and decrease in contraction and reflex time. Specific activities that can be utilized in the warm-up include calisthenics such as jumping jacks and running in place for 10 to 15 minutes prior to swinging a golf club. 5 -15 minutes of walking, cycling or easy jogging are also suggested to increase muscle and core temperature.

**Cardio-Respiratory Fitness**

Fatigue is among the major factors that decreases performance in golfers. The high skill level required, combined with the small margin for error with each shot, means that even a small level of fatigue may greatly decrease performance. Factors such as concentration, neuromuscular coordination and muscle strength will eventually be influenced by a fatigue. An increase in the level of cardio-respiratory fitness will enable the golfer to complete a round of golf feeling less exhausted and thus better able to continue to execute the many golfing skills to prevent fatigue. Cardio-vascular exercises are advised 3-4 times a week for 30-40mins to build up aerobic/ cardio-vascular / respiratory endurance.

**Flexibility**

Flexibility is the range of motion about a joint and its surrounding muscles; this is also known as static flexibility, whereas dynamic flexibility refers to the resistance of a joint during movement. Good flexibility is essential for playing golf. Golfers need a good range of motion of the lumber spine, flexibility of the trunk and hip musculature, spinal rotation and shoulder mobility to successfully execute the golf swing. A golfer with appropriate flexibility is therefore less likely to incur injury by exceeding tissue extensibility during the golf swing. This may then decrease the forces applied to the lumbar spine.
The following stretches are advised to be executed prior to a round of golf (3-4 times per week), as prevention for golf related back injuries:

<table>
<thead>
<tr>
<th>Stretch - Muscles utilized</th>
<th>Description of activity</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat stretch - Lumbar muscles</td>
<td>On hands and knees, flexion / extension stretch by tilting the pelvis and alternating arching and depressing the back</td>
<td><img src="image" alt="Cat stretch" /></td>
</tr>
<tr>
<td>Knee to chest sequence - lumbar paraspinal muscles / hip extensors</td>
<td>Pull knees to the chest and the head and neck to the knees while lying on your back. This can also be done by pulling both knees simultaneously towards the chest.</td>
<td><img src="image" alt="Knee to chest sequence" /></td>
</tr>
<tr>
<td>Prayer stretch - Back extensor muscles</td>
<td>Starting on hands and knees position with the back held flat the patient sits back down onto the heels and stretches the arms out in front.</td>
<td><img src="image" alt="Prayer stretch" /></td>
</tr>
<tr>
<td>Spinal rotation - lumbar rotation musculature</td>
<td>Start lying on the back with the knees bent and rolls both knees as close to the floor as comfortable. Secondly the legs are extended again and one leg is raised and lowered across the body to rotate the trunk (both sides)</td>
<td><img src="image" alt="Spinal rotation" /></td>
</tr>
<tr>
<td>Hamstring stretch – Hamstring, hip extension muscles</td>
<td>Each leg is elevated unto a chair or something equivalent with comfortable height, while the knees and the back are kept straight during forward bending until a slight pull is felt in the hamstrings. (Do not go beyond a stretch feeling)</td>
<td><img src="image" alt="Hamstring stretch" /></td>
</tr>
</tbody>
</table>
| Backswing Stretch with Club | • Step 1: Extend left arm out in front of you (if you are a right handed golfer).  
• Step 2: Take both hands and place on top of club.  
• Step 3: Drop upper body down against club to feel a stretch in your left shoulder.  
• Step 4: Hold at least 15 seconds, repeat once more, then do the opposite arm for your follow-through side. | ![Backswing Stretch](image) |

* Holding time of each stretch is 20-30 seconds, repeated 2-3 times. The stretches are performed in a slow, controlled manner, with no pain and natural breathing pattern:
**Strength**

The aim of strength exercise is to improve the strength of the golfer and their ability to generate power during the golf swing to increase club head speed. Due to the muscular demands of the golf swing and the prevalence of injury in the lumbar spine, training the trunk musculature may improve performance and decrease injury risk. Exercises performed in the injury prevention component may improve the golf swing and exercises performed during the strength and power component may reduce the risk of injury. Physical inactivity has been associated with reduced strength of the muscles of the trunk, and a direct correlation has been established between inactivity and chronic lower back pain. According to literature, the trunk muscles play a vital role and are utilized most in the golf swing. It is not surprising therefore that the majority of golf injuries occur at the location of these muscle groups. These muscle groups function to initiate and control the body while the golfer is performing the swinging motion. The repetitive swinging of the golf club can lead to fatigue in these muscles, increasing the risk for injury not only to the back, but also to secondary muscles as well.

The ability to stabilize the spine is considered necessary in the prevention of low back injuries. Spinal stability is not provided by one specific muscle but rather via the coordinated efforts of a group of muscles (rectus abdominis, external oblique, internal oblique, tranverse abdominis, erector spinae, quadratus lumborum and latissimus dorsi). Because only a minimal level of trunk muscle contraction appears necessary to stabilize the spine, the strength of these muscles appears less important than the endurance capabilities of the muscular stabilizing system. The aim of a golf exercise program is to improve the endurance and strength of trunk muscles to further facilitate their ability to stabilize the spine in neutral and non-neutral positions and improve their ability to produce force during the golf swing.

*These golf specific strengthening exercises are advised however require a gym and equipment:*
<table>
<thead>
<tr>
<th>Exercise</th>
<th>Description of activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable punch – pectoralis major and triceps brachii, all trunk and core stabilization muscles</td>
<td>This exercise is performed standing with the legs slightly bent, staggered and body weight on the balls of the feet. While keeping an athletic posture the golfer begins with the cable held lateral to and slightly in front of their chest. The golfer than presses their hand forward in line with the cable. The exercise creates an isometric torque about the lumbar spine which the golfer must resist while actively contracting the primary movers. The golfer can also make a slight twisting motion similar to throwing a punch or a football. In addition to training the primary movers this exercise requires a great deal of trunk muscle activity. The twisting motion is similar to the rotation occurring during the golf swing.</td>
</tr>
</tbody>
</table>
| Deadlift - leg muscles, buttocks, posterior trunk muscles, abs | Golfers should focus on allowing the buttocks to feel as if they are being pushed backwards. Body weight is on the heels similar to the golf address position. This exercise is added because it is an excellent all around exercise and is similar to the address position for all swings of the club.  
  *Do not use heavy weights at first, you can use your golf club alone then progress to adding small strap on weights (PT should advise) |
| Ball bridge                    | Patient lies on the back with a Swiss ball between the shoulder blades. The knees are bent, feet pointed straight ahead at shoulder-width. The abdomen is drawn in, activating the gluteal muscles, and lifting the pelvis until the knees are bent 90 degrees and a straight line can be drawn from shoulders to knees. This position is held and then slowly pelvis is lowered back toward the ground. |
| Floor two                      | Patient lays flat on the floor, knees bent, feet }
<table>
<thead>
<tr>
<th>Exercise</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg bridge</td>
<td>Flat, toes pointing straight ahead and arms by sides. Then the activate gluteal muscles are activated and hips are raised off the floor to form a straight line. This position is hold and the hack slowly returned to the ground.</td>
</tr>
<tr>
<td>Prone cobra</td>
<td>Patient lays face down on the floor with arms in front of the body and palms facing down. Then the gluteal muscles and abdominals are activated and the scapula retracted towards the midline of the body, lifting the chest off the floor while keeping the chin tucked. This position is held and then slowly the upper body is return to the floor.</td>
</tr>
<tr>
<td>Prone cobra plus (Advanced)</td>
<td>Advanced version of the above exercise, adding opposite arm with opposite leg. Place small cushion or ball under forehead.</td>
</tr>
<tr>
<td>Wood chopper plus weights (amount of weights personally chosen)</td>
<td>Patient stands with the arms fully extended overhead, and then the weight is slowly moved forward and down between the legs. As the weight is between the legs the knees and hips are flexed but the back stays straight.</td>
</tr>
<tr>
<td>Medical ball swing</td>
<td>Golfer simply assumes a golf stance, swings the ball back similar to the back swing but not more than halfway back and then swings forward releasing the ball while attempting to mimic the proper golf movement.</td>
</tr>
</tbody>
</table>
Postural Stability

Many commonly prescribed trunk muscle exercises for rehabilitation and performance may actually predispose one to injury due to the high compressive and shear loads imparted on the lumbar spine caused by excessive muscular co-contraction and extreme ranges of motion (Axler and McGill, 1997).

The exercises chosen by Lehman for stability currently have the most research supporting their ability to adequately activate the trunk musculature without exceeding cautious injury thresholds for compressive and shear loading (see below). The exercises are sufficient to adequately stress all trunk muscles responsible for maintaining a strong and stable spine. Lehman advises the performance of these stabilising exercises on the days that the athlete is not performing their strength exercises with the attempt to maintain a moderately neutral position while performing each exercise for 5 seconds.

Table III: Stability exercises

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Description of activity</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bird dog</td>
<td>Golfer starts on hands and knees. From this 4 point kneeling position the golfer should extend one leg parallel to the floor, hold for 3 seconds and return to the starting position, repeat with the other leg. Additionally, the opposite arm can also be raised. The golfer must maintain control of the spine and minimize twisting and excessive movement.</td>
<td><img src="image1" alt="Bird dog" /></td>
</tr>
<tr>
<td>Side support</td>
<td>Golfer starts in side lying position and raises their torso off the floor. Their weight should be supported by their knee and their forearm. To increase difficulty support the weight from the forearm and the golfers lateral feet.</td>
<td><img src="image2" alt="Side support" /></td>
</tr>
<tr>
<td>Front support</td>
<td>Rolling from the side support position the golfer maintains a neutral spine and supports their weight on their forearms and the balls of both feet.</td>
<td><img src="image3" alt="Front support" /></td>
</tr>
<tr>
<td>Curl up</td>
<td>Golfer lies on back with one knee bent 90 degrees and the second leg straight. Hands should be placed under the low back to prevent spinal flexion. Golfer “curls” their shoulders 2 inches off the surface. The neck should stay in a neutral position. Strain should be experienced in the abdominal region. The golfer should focus on curling the ribcage toward their pelvis.</td>
<td><img src="image4" alt="Curl up" /></td>
</tr>
</tbody>
</table>

Tips for golfers:

- Choose the longer club to allow for an easier swing, less rotational force, and less need for flexion over the ball. In addition, one should concentrate on maintaining arch in the lower lumbar region, “hinging” at the hips rather than actually flexing the spine.
• Consider slightly reducing the amount of rotation in your golf swing. When available, lessons or videotaping can help perfect this.
• Keep the number of practice swings to a minimum. The most strenuous golf activity for those with bad backs is driving a “bucket” of balls at driving range. Similarly, taking for or five practice swings before each shot during a game greatly overloads the structures of the back.
• When driving in the cart from one shot to the next, be sure to maintain an upright posture, do not slouch. If necessary, a lumbar pillow or seat can be of benefit.
• Avoid carrying one single heavy bag when walking the course. Purchase the lightest bag available, or at least alternate the bag from side to side so that the same shoulder does not carry the bag throughout the course.
• When bending to pick up a ball or club, face it squarely, bend with the knees, and maintain slight arch in the lower back. Too many people casually reach down as they rotate, then find it difficult to straighten back up.
• When in pain, seek help at once, what may at first feel normal and tolerable could turn into a chronic injury.

In The Golf Biomechanics Manual, Paul Check (1999) writes: “Amateur golfers achieve approximately 90 percent of their peak muscular activity when driving a golf ball. This is the same intensity as picking up a weight that can only be lifted four times before total fatigue. This level of exertion and muscular activation equates golf with such sports as football, hockey and martial arts. The difference is that other athletes outside of golf include conditioning as an integral part of their preparation before play”. Despite the fact that golf is considered a low intensity sport, it is associated with a significant number of injuries, most common, injury to the low back. Very few golfers attempt any conditioning or golf-specific exercising, is it any wonder there are so many golf-related injuries?
Appendix A: Literature Grading System

**Article Title:**

**Graded By:**

---

**General Inclusion Criteria List**

* Circle YES or NO according to the below general inclusion criteria. *If all items 1-6 are marked YES continue grading according to following categories listed. If the article does not meet the inclusion criteria it is excluded from further grading and is of no further useful value to this study. Other sources may be included if authors find objective reasons for them to be included.*

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>YES/NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Article search limited to only reliable, reputable journals from one of the following databases: Pub-med, Cochrane, Pi-carta, Cinahl, MEDLINE, Science Direct, Springer link, PiCarta, Cochrane and Pedro</td>
<td>YES/NO</td>
</tr>
<tr>
<td><strong>Reason:</strong> Assurance of a higher quality standard</td>
<td></td>
</tr>
<tr>
<td>2. All the articles should be written in the last 20 years</td>
<td>YES/NO</td>
</tr>
<tr>
<td><strong>Reason:</strong> To include the evolution of the golf swing through time</td>
<td></td>
</tr>
<tr>
<td>3. Only articles in the English, German, French, Arabic language can be used</td>
<td>YES/NO</td>
</tr>
<tr>
<td><strong>Reason:</strong> To get an international perspective of highest possible quality in evidence based research</td>
<td></td>
</tr>
<tr>
<td>4. All literature must be directly applicable to the target population of golfers</td>
<td>YES/NO</td>
</tr>
<tr>
<td><strong>Reason:</strong> To ensure relevance to our topic and clinical significance</td>
<td></td>
</tr>
<tr>
<td>5. All literature must be directly applicable to the science of physiotherapy</td>
<td>YES/NO</td>
</tr>
<tr>
<td><strong>Reason:</strong> To ensure relevance to our topic and clinical significance</td>
<td></td>
</tr>
<tr>
<td>6. All literature must contain one of the following keywords in category A, B and C in the article title.</td>
<td>YES/NO</td>
</tr>
<tr>
<td>A: Golf, Golf injuries, Golf sport, Golf injury prevention, Golf rehabilitation, rehabilitation, Golf Swing Biomechanics</td>
<td></td>
</tr>
<tr>
<td>B: assessment, assessment tool, physical examination, physiotherapy, physical therapy</td>
<td></td>
</tr>
<tr>
<td>C: Lumbar spine, back pain, lower back pain, herniated intervertebral disc, facet joints</td>
<td></td>
</tr>
<tr>
<td><strong>Reason:</strong> To ensure specificity to the research objective</td>
<td></td>
</tr>
</tbody>
</table>

**ARTICLE ACCEPTED** | YES/NO |
Evidence Level grading list

* Grade the article only after it meets the inclusion criteria. Follow the below questions and score with an unbiased approach

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>MAX POINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td></td>
</tr>
</tbody>
</table>
| The abstract contains sufficient information of subjects, methods, results and conclusion  
(To give the reader the most important key points of the study and give interest to read further) | /8         |
| **Introduction**                                                        |            |
| There is sufficient medical background which logically leads to the research question  
(It is the intention of the research and therefore should be stated to give clarity to the reader. Since one can be inferred from the other it is only necessary to clearly state one.) | /6         |
| The purpose and the hypothesis of the study are clearly stated  
(It is the intention of the research and therefore should be stated to give clarity to the reader. Since one can be inferred from the other it is only necessary to clearly state one.) | /4         |
| **Methods**                                                             |            |
| Eligibility criteria are stated  
(Criterion is important for external and internal validity ) | /6         |
| The settings and subjects are clearly stated  
(Criterion is important for external validity.) | /4         |
| The design of the study is accurately explained, defining inclusion and exclusion criteria  
(The baseline of the study should be clearly defined and expressed to the reader to ensure internal/external validity) | /6         |
| Sufficient information of the procedure is given, reproducibility is warranted  
(To ensure that the results of the study are truly valid and reliable) | /6         |
| Selected material / instruments are described and validity is given  
(To insure that internal validity is given) | /6         |
| The research groups are similar at baseline regarding the most important prognostic factors  
(To insure that the groups are comparable and that there are no external factors that may skew outcome results.) | /4         |
Results

The presentation of the results is appropriate and complete, tables are clearly constructed
(The presentation of results has to be clear, organised and complete to clarify presented results and relate them understandably to the reader)

Description of all outcome measurement scales are given
(Only through a clear description outcome measurement scales become clear to the reader)

P-value is stated and significance level mentioned
(to verify the outcome of the study and highlight the level of evidence, from which conclusions will be drawn)

Conclusion and discussion

The methods are discussed in respect to internal and external validity
(Basing the interpretation of results on internal/external validity ensures that the conclusions the authors draw are based on scientific evidence, and not just on their personal opinions.)

The conclusion follows the data reported
(to show the logical build up of the study the article must draw the conclusion based on the results of the data analysis)

The conclusion gives an answer on the hypothesis / research question
(The results are the answer to the research question and therefore should be made readily available to the reader.)

Usefulness

General usefulness to PT profession

Specifically useful for the creation of the guideline

<table>
<thead>
<tr>
<th>Points</th>
<th>Evidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systematic reviews</td>
<td>A* Excellent</td>
</tr>
<tr>
<td>85-100</td>
<td>A Very Good</td>
</tr>
<tr>
<td>70-84</td>
<td>B Good</td>
</tr>
<tr>
<td>55-69</td>
<td>C Fair</td>
</tr>
<tr>
<td>40-54</td>
<td>D Sufficient</td>
</tr>
<tr>
<td>&lt;40</td>
<td>E Insufficient</td>
</tr>
<tr>
<td>Sources other than articles</td>
<td>N/A Useful / non useful</td>
</tr>
</tbody>
</table>

TOTAL /100

Table 3: Evidence Levels
## Appendix B: Literature Grading List

<table>
<thead>
<tr>
<th>Article</th>
<th>Grade</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allison, G.T. &amp; Henry, S.M. (2001). Trunk muscle fatigue during a back extension task in standing. <em>Manual Therapy</em>, 6(4), pp. 221-228.</td>
<td>A</td>
<td>Biersen - soerensopn This test has been shown to be reliable between trials, and sensitive between individuals with and without low back pain (LBP) (Latimer et al. 1999).</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-----</td>
<td>------</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Title</th>
<th>Year</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Murphy, D.R., Byfield, D., McCarthy, P., Humphreys, K., Gregory, A.A. &amp; Rochon, R. (2005).</td>
<td>Interexaminer reliability of the hip extension test for suspected impaired motor control of the lumbar spine.</td>
<td>Journal of Manipulative and Physiological Therapeutics, 29(5).</td>
<td>B In the pelvis, the active straight leg raise test has been shown to be reliable and valid. Hicks et al found good interexaminer reliability of the bprone instability test, which shows promise in assessing the stability response to shear forces.</td>
</tr>
<tr>
<td>NHMRC: National Health and Medical Research Council.</td>
<td>A guide to the development, implementation and evaluation of clinical practice guidelines.</td>
<td>N/A Authors unknown</td>
<td></td>
</tr>
<tr>
<td>Author(s)</td>
<td>Title</td>
<td>Source</td>
<td></td>
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</tr>
<tr>
<td>Pearcy, M. J. &amp; Tibrewal, S.B.</td>
<td>Axial rotation and lateral bending in the normal lumbar spine measured by three dimensional radiography</td>
<td><em>Spine</em>, 9, p. 582.</td>
<td></td>
</tr>
<tr>
<td>Reed, J.</td>
<td>Strength and Conditioning Strategies to Reduce the Risk of Lower Back Injuries Associated With the Golf Swing</td>
<td><em>Strength and Conditioning Journal</em>.</td>
<td></td>
</tr>
</tbody>
</table>

A: Original Research Article
B: Book
C: Book Chapter
D: Review Article

The results suggest that experienced therapists who had trained together were able to agree on the results of examinations and obtain an acceptable level of reliability. Future work should focus on testing of reliability when more than one therapist performs the examination and when therapists not trained by the test developer to administer the examination perform the tests.

---


Verkerk et al. (2006) did not specify the type of evidence-based guideline (Guideline).


B


A *


A


B


B


B Not golf specific


N/A Book


C Pathologies


C Prevention
## Appendix C: Assessment tool List

<table>
<thead>
<tr>
<th>Test of Lasegue: Straight leg raising</th>
<th>Purpose of test</th>
<th>Name of article</th>
<th>Author</th>
<th>Validity</th>
<th>Reliability</th>
<th>Specificity</th>
<th>Sensitivity</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>Neurodynamic test to evaluate the mechanical movement of the neurological tissue and to test their sensitivity to mechanical stress or compression/ flexibility of hamstrings</td>
<td>The Test of Lasegue: Systematic Review of the Accuracy in Diagnosing Herniated Discs</td>
<td>Deville et al.</td>
<td>Low</td>
<td>High</td>
<td>moderately accurate (Hoogan, van den et al.1995) most appropriate test for lower lumber nerve roots (Deyo et al.1992)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relationship of Physical Examination Findings and Self-Reported Symptom Severity and Physical Function in Patients With Degenerative Lumbar Conditions</td>
<td></td>
<td>Lyle et al. 2005</td>
<td>satisfactory reliability between raters</td>
<td></td>
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<tr>
<td>Diagnostic value of history and physical examination in patients suspected of sciatica due to disc herniation: a systematic review.</td>
<td></td>
<td>Vroomen et al. 1999</td>
<td>0.52</td>
<td>0.85</td>
<td></td>
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<tr>
<td>Active SLR</td>
<td>The ASLR was performed as described by Mens et al. to assess the ability of the pelvic girdle to transfer loads between the lumbopelvic region and the legs. Muscular strength and flexibility/ proprioception</td>
<td>Reliability and validity of the active straight leg raise test in posterior pelvic pain since pregnancy</td>
<td>Mens at al. 2001</td>
<td>Good</td>
<td>Good</td>
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<tr>
<td>Interexaminer reliability of the hip extension test for suspected impaired motor control of the lumbar spine.</td>
<td></td>
<td>Murphy et al. 2005</td>
<td>In the pelvis, the active straight leg raise test has been shown to be reliable and valid.</td>
<td></td>
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<tr>
<td>Crossed SLR</td>
<td>Muscular strength and flexibility/ proprioception</td>
<td>Diagnostic value of history and physical examination in patients suspected of sciatica</td>
<td>Vroomen et al. 1999</td>
<td>0.84</td>
<td>0.30</td>
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<tr>
<td>Test</td>
<td>Description</td>
<td>Reference</td>
<td>Intrepretation</td>
<td>Reliability</td>
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<td></td>
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<tr>
<td>Slump test</td>
<td>Neurodynamic test to evaluate the mechanical movement of the neurological tissue and to test their sensitivity to mechanical stress or compression. Use of lumbar extension, slump test, physical and neurological examination in the evaluation of patients with suspected herniated nucleus pulposus. A prospective clinical study.</td>
<td>Stankovic et al. 1999</td>
<td>Moderate</td>
<td>High</td>
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<tr>
<td></td>
<td></td>
<td>Nelson et al. 1979</td>
<td></td>
<td>General reliability low</td>
<td></td>
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<tr>
<td>Quadrant test</td>
<td>Screening test for the assessment of facet joint dysfunction.</td>
<td>Relationship of Physical Examination Findings and Self-Reported Symptom Severity &amp; Physical Function in Patients With Degenerative Lumbar conditions</td>
<td>Lyle et al. 2005</td>
<td>Quadrant test distinguished those subjects with clinically meaningful low back symptom severity but was not predictive of impaired function. The quadrant test was the most common test that reproduced the patients' symptoms.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Interexaminer Reliability in Physical Examination of Patients with Low Back Pain.</td>
<td>Strender et al. 1997</td>
<td>High interrater reliability</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Schober test</td>
<td>Sagittal Lumber Spine Range of motion</td>
<td>Use of lumbar extension, slump test, physical and neurological examination in the evaluation of patients with suspected herniated nucleus pulposus. A prospective clinical study.</td>
<td>Stankovic et al. 1999</td>
<td>Inrrater r= 0.95 / interrater 0.94</td>
<td></td>
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</tr>
<tr>
<td>Mod Schober test</td>
<td>Sagittal Lumber Spine Range of motion</td>
<td></td>
<td>Mod Schober test</td>
<td>Modified interrater r= 0.71</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Measurement of range of movement in the lumbar Spine—what methods are valid? A systematic review</td>
<td>Littlewood and Mayb 2006</td>
<td>No prove that the test is not valid compared to golden standard</td>
<td></td>
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<tr>
<td>Test</td>
<td>Description</td>
<td>Study/Reference</td>
<td>Endurance/Reliability</td>
<td>Comment</td>
<td></td>
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<tr>
<td><strong>Biering Sorensen Test</strong></td>
<td>Endurance of trunk extensor muscles</td>
<td>Latimer et al. 1999, Allison &amp; Henry 2001</td>
<td>High between trials, satisfactory intraobserver reproducibility in healthy and LBP patients</td>
<td>High in between individuals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **Isometric Back Extension**     | Endurance Tests: A Review of the Literature                                  | Moreau et al. 2001                                                              | - global measure of back extension endurance capacity                                 | - test-retest reliability 0.54 till 0.99  
- high intra-class correlation for active LBP patients (0.82 – 0.96), respectively lower for inactive ones  
- interrater reliability of 0.80  
Age has a significant negative correlation with the Sorensen test, reported by 3 studies  
Percent body fat and weight have significantly negative associations with the Sorensen test in 3 studies  
No significant correlation with Sorensen endurance times was observed with the following: maximum isometric strength, a psychophysical lift test, perception of strain during the test, extensor muscle torque, measurements of lower limb length or inequality, smoking, prior physical training, cross-sectional area of back extensor muscles, cross-sectional area of the psoas muscle, or trunk flexion endurance. Safe procedure for testing subjects with or without LBP. |
| **Reliability of the Isokinetic**| Trunk Extensor Test, Biering-Sorensen Test, and Astrand Bicycle Test         | Keller et al. 2001                                                              | High reliability in the assessment of LBP patient but not in healthy individuals     | The Critical Difference for the Biering-Sorensen test was high in both the patients and the healthy individuals (57% vs. 54%). Reliability also depends on scale to grade reliability!! |
| **Pain on trunk motion**         | Active lumbar flexion, extension, lateral flexion                           | Relationship of Physical Examination Findings and Self-Reported Symptom Severity and Physical Function in Patients With Degenerative Lumbar Conditions | Good Interrater reliability                                                         |                                                                                                                                                                                                                                    |
| **Hip extension test**           | Extension test for suspected impaired motor control of the lumber spine     | Interexaminer reliability of the hip extension test for suspected impaired motor control of the lumber spine | Validity with regard to the test’s ability to distinguish patients with chronic low  
Good interexaminer reliability in detecting deviation of the lumbar spine             |                                                                                                                                                                                                                                    |
<table>
<thead>
<tr>
<th><strong>&quot;Revel's criteria&quot;</strong></th>
<th>Screening test for the assessment of the Zygapophysial joints (standing flexion, returning from standing flexion, standing extension, the extension rotation test)</th>
<th>Zygapophysial joint blocks in chronic low back pain: a test of Revel's model as a screening test</th>
<th>Laslett et al. 2004</th>
<th>high</th>
<th>Low</th>
<th>unsuitable as a clinical screening test to select chronic LBP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lumber extension test (McKenzie)</strong></td>
<td>Use of lumbar extension, slump test, physical and neurological examination in the evaluation of patients with suspected herniated nucleus pulposus. A prospective clinical study</td>
<td></td>
<td>Stankovic et al. 1999</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Reflexes</strong></td>
<td>Use of lumbar extension, slump test, physical and neurological examination in the evaluation of patients with suspected herniated nucleus pulposus. A prospective clinical study</td>
<td></td>
<td>Stankovic et al. 1999</td>
<td></td>
<td></td>
<td>The symptoms do not always provide a clear diagnosis of the level. The absence of an achilles reflex is more indicative of disc prolapse than impairment of this reflex. In the present study no sig differences between groups were noticed for muscle weakness, sensory impairments or reflex depressions</td>
</tr>
<tr>
<td><strong>Oswestry disability index</strong></td>
<td>Pain / disability scale</td>
<td>Rasch analysis of three versions of the Oswestry Disability Questionnaire</td>
<td>Davidson 2007</td>
<td></td>
<td></td>
<td>Good functional response</td>
</tr>
</tbody>
</table>
Appendix D: Modified Oswestry Low Back Pain Disability Questionnaire

This questionnaire has been designed to give your therapist information as to how your back pain has affected your ability to manage in everyday life. Please answer every question by placing a mark in the one box that best describes your condition today. We realize you may feel that 2 of the statements may describe your condition, but please mark only the box that most closely describes your current condition.

Pain Intensity
! I can tolerate the pain I have without having to use pain medication.
! The pain is bad, but I can manage without having to take pain medication.
! Pain medication provides me with complete relief from pain.
! Pain medication provides me with moderate relief from pain.
! Pain medication provides me with little relief from pain.
! Pain medication has no effect on my pain.

Personal Care (e.g., Washing, Dressing)
! I can take care of myself normally without causing increased pain.
! I can take care of myself normally, but it increases my pain.
! It is painful to take care of myself, and I am slow and careful.
! I need help, but I am able to manage most of my personal care.
! I need help every day in most aspects of my care.
! I do not get dressed, I wash with difficulty, and I stay in bed.

Lifting
! I can lift heavy weights without increased pain.
! I can lift heavy weights, but it causes increased pain.
! Pain prevents me from lifting heavy weights off the floor, but I can manage if the weights are conveniently positioned (e.g., on a table).
! Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned.
! I can lift only very light weights.
! I cannot lift or carry anything at all.

Walking
! Pain does not prevent me from walking any distance.
! Pain prevents me from walking more than 1 mile. (1 mile = 1.6 km).
! Pain prevents me from walking more than 1/2 mile.
! Pain prevents me from walking more than 1/4 mile.
! I can walk only with crutches or a cane.
! I am in bed most of the time and have to crawl to the toilet.

Sitting
! I can sit in any chair as long as I like.
! I can only sit in my favorite chair as long as I like.
! Pain prevents me from sitting for more than 1 hour.
! Pain prevents me from sitting for more than 1/2 hour.
! Pain prevents me from sitting for more than 10 minutes.
! Pain prevents me from sitting at all.

Standing
! I can stand as long as I want without increased pain.
! I can stand as long as I want, but it increases my pain.
Pain prevents me from standing for more than 1 hour.
Pain prevents me from standing for more than 1/2 hour.
Pain prevents me from standing for more than 10 minutes.
Pain prevents me from standing at all.

Sleeping
Pain does not prevent me from sleeping well.
I can sleep well only by using pain medication.
Even when I take medication, I sleep less than 6 hours.
Even when I take medication, I sleep less than 4 hours.
Even when I take medication, I sleep less than 2 hours.
Pain prevents me from sleeping at all.

Social Life
My social life is normal and does not increase my pain.
My social life is normal, but it increases my level of pain.
Pain prevents me from participating in more energetic activities (e.g., sports, dancing).
Pain prevents me from going out very often.
Pain has restricted my social life to my home.
Pain prevents me from having any social life because of my pain.

Traveling
I can travel anywhere without increased pain.
I can travel anywhere, but it increases my pain.
My pain restricts my travel over 2 hours.
My pain restricts my travel over 1 hour.
My pain restricts my travel to short necessary journeys under 1/2 hour.
My pain prevents all travel except for visits to the physician / therapist or hospital.

Employment / Homemaking
My normal homemaking / job activities do not cause pain.
My normal homemaking / job activities increase my pain, but
I can still perform all that is required of me.
I can perform most of my homemaking / job duties, but pain prevents me from
performing more physically stressful activities (e.g., lifting, vacuuming).
Pain prevents me from doing anything but light duties.
Pain prevents me from doing even light duties.
Pain prevents me from performing any job or homemaking chores.


APPENDIX E: Golf Specific Evaluation Form

Golf Assessment Structural & Functional Evaluation Form

Name: _________________________                Index:_______                        Date:____

Referring Physician: ____________________

Medical Diagnosis:  Intervertebral Disc Pathology/Facet Joint Pathology
Main Complaint:
Primary Objective/Goal (Realistic):
Red Flags:
Yellow Flags:
Occupation:
Hours played per week:

Pain: Fill out Oswestry Questionnaire (appendix D)
Time of onset:  distinct/gradual
Superficial & local/ deep & general
Increases in what position ______________
Which part of the golf swing exacerbates the pain

Physical Examination

• Active Range of Motion
• Passive ROM
• Muscle testing
• Isometric extensor endurance test (Beiring-Sorensen test)
• Proprioception/Postural stability
• Single leg stance test
• Balance
• Star Excursion Balance Test

Functional Assessment : swing analysis

Special Tests
SLR
Active SLR
Crossed SLR
Slump Test
Quadrant Test
Schober test
Hip extension test
Revel’s criteria
McKenzie/lumbar extension test
Reflex testing

Other Notes:
## Golf specific prevention protocol

<table>
<thead>
<tr>
<th>Stretch - Muscles utilized</th>
<th>Description of activity</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat stretch - Lumbar muscles</td>
<td>On hands and knees, flexion / extension stretch by tilting the pelvis and alternating arching and depressing the back</td>
<td><img src="image1" alt="Cat stretch" /></td>
</tr>
<tr>
<td>Knee to chest sequence - lumbar paraspinal muscles / hip extensors</td>
<td>pull knees to the chest and the head and neck to the knees while lying on your back. This can also be done by pulling both knees simultaneously towards the chest.</td>
<td><img src="image2" alt="Knee to chest sequence" /></td>
</tr>
<tr>
<td>Prayer stretch - Back extensor muscles</td>
<td>Starting on hands and knees position with the back held flat the patient sits back down onto the heels and stretches the arms out in front.</td>
<td><img src="image3" alt="Prayer stretch" /></td>
</tr>
<tr>
<td>Spinal rotation - lumbar rotation musculature</td>
<td>Start lying on the back with the knees bent and rolls both knees as close to the floor as comfortable. Secondly the legs are extended again and one leg is raised and lowered across the body to rotate the trunk (both sides)</td>
<td><img src="image4" alt="Spinal rotation" /></td>
</tr>
<tr>
<td>Hamstring stretch – Hamstring, hip extension muscles</td>
<td>Each leg is elevated unto a chair or something equivalent with comfortable height, while the knees and the back are kept straight during forward bending until a slight pull is felt in the hamstrings. (Do not go beyond a stretch feeling)</td>
<td><img src="image5" alt="Hamstring stretch" /></td>
</tr>
</tbody>
</table>
| Backswing Stretch with Club | • Step 1: Extend left arm out in front of you (if you are a right handed golfer).  
• Step 2: Take both hands and place on top of club.  
• Step 3: Drop upper body down against club to feel a stretch in your left shoulder.  
• Step 4: Hold at least 15 seconds, repeat once more, then do the opposite arm for your follow-through side. | ![Backswing Stretch](image6) |
<table>
<thead>
<tr>
<th>Exercise</th>
<th>Description of activity</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable punch</td>
<td>This exercise is performed standing with the legs slightly bent, staggered and body weight on the balls of the feet. While keeping an athletic posture the golfer begins with the cable held lateral to and slightly in front of their chest. The golfer than presses their hand forward in line with the cable. The exercise creates an isometric torque about the lumbar spine which the golfer must resist while actively contracting the primary movers. The golfer can also make a slight twisting motion similar to throwing a punch or a football. In addition to training the primary movers this exercise requires a great deal of trunk muscle activity. The twisting motion is similar to the rotation occurring during the golf swing.</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>Deadlift</td>
<td>Golfers should focus on allowing the buttocks to feel as if they are being pushed backwards. Body weight is on the heels similar to the golf address position. This exercise is added because it is an excellent all around exercise and is similar to the address position for all swings of the club. <em>Do not use heavy weights at first, you can use your golf club alone then progress to adding small strap on weights (PT should advise)</em></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>Ball bridge</td>
<td>Patient lies on the back with a Swiss ball between the shoulder blades. The knees are bent, feet pointed straight ahead at shoulder-width. The abdomen is drawn in, activating the gluteal muscles, and lifting the pelvis until the knees are bent 90 degrees and a straight line can be drawn from shoulders to knees. This position is held and then slowly pelvis is lowered back toward the ground.</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>Exercise</td>
<td>Description</td>
<td>Image</td>
</tr>
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</tr>
<tr>
<td>Floor two leg bridge</td>
<td>Patient lays flat on the floor, knees bent, feet flat, toes pointing straight ahead and arms by sides. Then the activate gluteal muscles are activated and hips are raised off the floor to form a straight line. This position is hold and the hack slowly returned to the ground.</td>
<td><img src="image" alt="Floor two leg bridge" /></td>
</tr>
<tr>
<td>Prone cobra</td>
<td>Patient lays face down on the floor with arms in front of the body and palms facing down. Then the gluteal muscles and abdominals are activated and the scapula retracted towards the midline of the body, lifting the chest off the floor while keeping the chin tucked. This position is held and then slowly the upper body is return to the floor.</td>
<td><img src="image" alt="Prone cobra" /></td>
</tr>
<tr>
<td>Prone cobra plus (Advanced)</td>
<td>Advanced version of the above exercise, adding opposite arm with opposite leg. Place small cussion or ball under forehead.</td>
<td><img src="image" alt="Prone cobra plus" /></td>
</tr>
<tr>
<td>Wood chopper plus weights (amount of weights personally chosen)</td>
<td>Patient stands with the arms fully extended overhead, and then the weight is slowly moved forward and down between the legs. As the weight is between the legs the knees and hips are flexed but the back stays straight.</td>
<td><img src="image" alt="Wood chopper plus weights" /></td>
</tr>
<tr>
<td>Medical ball swing</td>
<td>Golfer simply assumes a golf stance, swings the ball back similar to the back swing but not more than halfway back and then swings forward releasing the ball while attempting to mimic the proper golf movement.</td>
<td><img src="image" alt="Medical ball swing" /></td>
</tr>
<tr>
<td>Exercise</td>
<td>Description of activity</td>
<td>Picture</td>
</tr>
<tr>
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</tr>
<tr>
<td>Bird dog</td>
<td>Golfer starts on hands and knees. From this 4 point kneeling position the golfer should extend one leg parallel to the floor, hold for 3 seconds and return to the starting position, repeat with the other leg. Additionally, the opposite arm can also be raised. The golfer must maintain control of the spine and minimize twisting and excessive movement.</td>
<td><img src="image1" alt="Bird dog" /></td>
</tr>
<tr>
<td>Side support</td>
<td>Golfer starts in side lying position and raises their torso off the floor. Their weight should be supported by their knee and their forearm. To increase difficulty support the weight from the forearm and the golfer's lateral feet.</td>
<td><img src="image2" alt="Side support" /></td>
</tr>
<tr>
<td>Front support</td>
<td>Rolling from the side support position the golfer maintains a neutral spine and supports their weight on their forearms and the balls of both feet.</td>
<td><img src="image3" alt="Front support" /></td>
</tr>
<tr>
<td>Curl up</td>
<td>Golfer lies on back with one knee bent 90 degrees and the second leg straight. Hands should be placed under the low back to prevent spinal flexion. Golfer “curls” their shoulders 2 inches off the surface. The neck should stay in a neutral position. Strain should be experienced in the abdominal region. The golfer should focus on curling the ribcage toward their pelvis.</td>
<td><img src="image4" alt="Curl up" /></td>
</tr>
</tbody>
</table>
APPENDIX F: Golf Glossary

Abnormal ground Conditions - Any of several conditions that, when they exist and your golf ball is affected by them, entitle the player to relief. Abnormal ground conditions include casual water, ground under repair and holes made by burrowing animals (e.g., gopher hole or snake hole). Holes dug by the green keeper are considered ground under repair even if they are not marked as such. A few things that are not considered abnormal ground conditions: dew or frost; a hole dug by an animal that is not a burrowing animal, unless so declared by the local committee; grass clippings. You cannot cite the abnormal ground conditions rule to take free relief if your ball is in a water hazard or lateral water hazard.

Address - The position a golfer takes as he or she stands over the ball, ready to hit - the stance is taken and the club is grounded. The club must have been grounded for a golfer to be considered at address (this distinction matters in many rules interpretations).

Also Known As: At address, address the ball, addressing the ball

Alignment - the direction that the body and club are “lined up” in the address position
Example: Standard issue alignment is parallel to the target line with a square clubface. An easy way to visualize this alignment is to imagine a railroad track -- your feet are standing on one track; the clubface is on, and square to, the other.

Amateur - Golfer who plays about 3 hours +/- 1.4 days per week

Approach Shot - A golf shot that is made from a distance (rough or fairway) towards the green.

Apron - The grass surface on the perimeter of the green that separates it from the fairway.

Away - farthest from the hole. Example: The player who is away plays first.

Back nine - (also "back side") the last 9 holes (10-18) of an 18 hole golf course

Backspin - The backward rotation of a golf ball in flight around a horizontal axis as caused by the club hitting the ball. The more loft on a club, the greater the backspin. Certain finishes on a club face (e.g., milling, brass-blasting) can also increase backspin.

Backswing - the backward movement of the body and club (away from the ball and target) in the golf swing in preparation for the downswing

Ball position - the position of the ball relative to a player's stance and the target at address

Birdie - A score on a golf hole that is one less than Par.

Bogey - A score on a golf hole that is one more than Par.

Carry – 1. the distance a ball travels in the air 2. the distance a ball must travel in the air in order to clear something or reach some destination

Cast - a common tendency to actively uncock the wrists and throw the club with the hands too early in the downswing in an attempt to accelerate the club or square the face 2. (as in "cast irons") a process of manufacturing clubheads where stainless steel (containing varying amounts of nickel) is poured into a mold in molten state and removed as one piece

Club professional - a golf professional associated with the operation of a golf facility, specifically as opposed to a Touring professional golfer

Club head - the most massive part of the club at the bottom end (opposite the grip or handle) of the shaft (ideally the part of the club that makes contact with the ball)

Club head speed - the speed that the clubhead is travelling through impact (usually measured in miles per hour)

Coefficient of restitution - (also "COR, C.O.R.") a measurement, expressed as a percentage, of how efficiently a ball bounces off the club face -- phrase became popular with the advent of "trampoline effect" or "spring-like effect" drivers and equipment/rules controversy (formula: COR = ball speed after contact - club speed after contact / club speed before contact)

Coil - the turning of the body away from the target in the backswing (generally thought of as
the turning of the shoulders against the lower body, like the coil of a spring)

come out of it - raising of the posture too early in the downswing

CPM - ("cycles per minute") most common unit used in measuring shaft flexes or frequencies (more precise than L, R, S, X, etc.)

Cross-handed - a grip where (for right-handers) the left hand would be the lowest hand instead of the right (usually associated with putting)

Divot - This is the piece of grass that is often removed from the turf when a golf shot is made. It is common golf etiquette to replace the divot when possible.

Downswing - (also "downward swing, forward swing") the portion of the swing that starts from the top, or end, of the backswing (or transition) and reverses movement and momentum back in the direction of the ball and target

Draw - (also "slinger, turn over, turn it over") a shot that curves gently from right to left (right-handed player)

Drive - the first shot on a (usually) par 4 or par 5 hole (most commonly used in reference to the driver or #1 wood)

Driver - The club that used to hit the ball for the first shot on a par 4 or par 5 hole. The longest hitting club in the set. Drivers commonly have lofts between 7 and 12 degrees.

Driving Iron - A golf club with low loft and a muscle or hollow body similar to a wood. The driving iron is a utility club most commonly used by golfers who have difficulty hitting their long irons.

Driving range - (also "practice range, practice tee, range") an area, separate from the golf course, designated for hitting practice balls

Elite / Professional golfer - Golfer with a handicap of 1-9 and who plays about 6 to 10 hours per day,

Face Angle - Position of the club face relative to the intended line of ball flight. For right-handed golfers, a square face angle aligns directly at the target; an open face aligns to the right, while a closed face aligns left.

Facet joint - facet joint or zygapophyseal joint is a synovial joint between the superior articular process of one (lower) vertebra and the inferior articular process of the adjacent (higher) vertebra. There are two facet joints in each vertebral motion segment. The biomechanical function of each pair of facet joints is to prevent excessive torsion of the spine, while allowing a small amount of lateral bending, flexion and extension.

Fairway - This is the area of a golf hole between the Tee and the Green. It is closely mown in compared to the rough making it easier to strike the golf ball cleanly.

Fall line - the natural and most direct downhill course of a given slope, the path water would take, or that gravity would dictate, down a slope without obstacles

Finish position - (also just "finish") the last position, or end, of the swing

Flat - a relatively shallow or more horizontal swing plane or lie angle

Flex - (also "frequency") the relative strength (stiffness or softness) of a club shaft

Foot wedge - kicking the ball against the rules

Full finger grip - (also "baseball, ten finger" grip) a method of holding the club using all ten fingers on the grip with no overlapping or interlocking fingers

GHIN - (Golf Handicap & Information Network) handicap service begun in 1981 maintained by the USGA

Golf - a game played with a small ball and a set of clubs, the object being to hit the ball into each of a series of holes with the smallest possible number of strokes -- of uncertain origin but may have originated with a game called chole, is supposedly the Celtic word for "ball" and also may come from the Old Dutch or Old German word "kolb" or "kolven" meaning "club" or "clubs"

Green - This is where the golf hole resides. The grass is very short and very smooth. Once the
golf ball is on the Green, it is typically putted toward the hole.

**Green fee** - the fee paid to play a course

**Grind** – 1. maintaining or intensifying one's mental focus, similar to the expressions "bear down" or "stay focused" -- generally meaning to concentrate on every shot and not get distracted

2. (also "Custom Grind") generic label referring to some proprietary iron head or sole shape, usually on forged irons -- could also refer to the fact that some players alter their own clubs (swing weight, flange shape, etc.) using a grinding wheel

**Half shot** - (also "half swing, knockdown, knockdown shot, punch, punch shot") a shot played with less than a full swing, mainly to control distance, trajectory and spin

**Handicap** - (abbr: "hcp, hdcp", related: "handicap differential, handicap index, index") the average difference between a player's scores and a set standard, as calculated by specified procedures and formulas

**Hole** - Can refer to each section of a golf course from the tee to the green as well as the actual hole or cup in the ground where the golfer is trying to hit the ball into. There are typically 18 holes on a given golf course or round.

**Hole in one** - (also "ace") a score of 1 on a hole, holing the tee shot

**Hook** - A shot that curves quickly to the left (for a right-handed golfer). Usually this is a miss-hit and not something the golfer is trying to do.

**Intervertebral disc** – intervertebral discs are disc shaped fibrocartilage which lies between adjacent vertebrae in the spine. Each disc forms a cartilaginous joint to allow slight movement of the vertebrae and acts as a ligament to hold the vertebrae together.

**Iron** - A golf club that has a flat metal head. There are different lofts given by numbers for each type of Iron club. The higher the number the more loft. Irons are used from most any position on the golf course except for the green.

**Lie** - The angle from the shaft to the ground line when the club is measured in normal playing position.

**Lift** - Upward force on a golf ball as it flies.

**Line** - 1. "target line, intended line") direction, as indicated by a vertical plane

2. ("line, line of a putt, putting line") the path on which the ball rolls, or will roll, enroute to the hole.

**LPGA** - (Ladies Professional Golf Association) formed to organize and promote women in professional golf

**Line up** - ( also "align") position/direct/orient the body and/or club

2. assessing the direction of a shot or putt

**Low Balance Point (LBP)** - A shaft with a high percentage of its weight toward the tip.

**Major** – 1. one of four annual tournaments (The Masters, U.S. Open, British Open or PGA)

2. could also refer to a tournament of greater significance than usual due to tradition or the sanctioning body

**Mark** - (also "spot") to put down a ballmarker (usually a small flat object, like a dime) to be able to replace the ball precisely in its original location after lifting (usually, but not exclusively, on the green)

**Marker** - (also "ball marker") usually a small, flat object (like a dime) used to mark the ball's position (usually, but not exclusively, on the green) while other players putt and/or the ball is cleaned

**Muscle memory** - a phrase referring to the nervous system's ability to memorize, or perform automatically, a well rehearsed motion

**Net** - a players score after a handicap has been applied

**OB** (also "O.B., out of bounds, Oscar Brown") out of bounds, off the golf course premises (usually marked with white stakes or property fences)

**Open**

1. a tournament in which any eligible competitor can play, if they qualify

2. ("open clubface, open stance") refers to the alignment of the body/stance or clubface - for a right-handed player the stance would be open if the body were aligned to the left of the target and an open
clubface would be aimed to the right of the target

**Example:** 1. The British Open, being the oldest organized tournament in the world, is sometimes simply referred to as The Open.

**Overlapping grip** - (also "overlap" and "Vardon grip" after famous player, Harry Vardon) the most common grip in golf, placing the hands on the club such that the pinky finger of the bottom hand rests on the index finger of the top hand, or between the index and middle fingers of the top hand

**Overswing** - 1. to swing too hard to the point of negatively affecting the result 2. too long a backswing, usually thought of in terms of well beyond the point of the club's shaft being horizontal or parallel with the ground at the end of the backswing

**Oversize Wood Head** - A wood head with volume greater than 200 cc's.

**Par** - This is the score that an expert golfer would be expected to make for the hole or golf course. Holes can have a Par score of 3, 4, or 5. Par for golf courses vary as well, but tend to be in the area of 72 strokes.

**Putter** - This is the golf club that is used on the Green. It is used to strike the golf ball such that it roles into the golf hole.

**Release** – 1. (also "let it go") generally thought of as the act of allowing the centrifugal force of the body/arms/hands/clubhead to take its course on the downswing rather than holding on or inhibiting it (can be broken down into specifics) 2. when a ball stops spinning backward and starts to roll forward

**Reliability** – index of the consistency of a measuring instrument in repeatedly providing the same score for a given subject. There are many different types of reliability, each referring to a different aspect of consistency. Types of reliability include interrater reliability, test-retest reliability and internal consistency reliability.

**Reverse overlap** - ("reverse overlap grip") probably the most common grip used for putting - a method of placing the hands on the club such that the index finger of the top hand rests on top of the fingers of the bottom hand

**Rules of golf** - regulations and procedures of the game as set forth by a collaborative effort of the Royal and Ancient Golf Club of St. Andrews in Scotland and the United States Golf Association

**Rough** - An area outside of the Fairway. The grass is longer making it harder to hit the golf ball cleanly.

**Sensitivity** – statistical measure of how well a binary classification test correctly identifies a condition, whether this is medical screening tests picking up on a disease, or quality control in factories deciding if a new product is good enough to be sold. The results of the screening test are compared to some absolute (Gold standard); for example, for a medical test to determine if a person has a certain disease, the sensitivity to the disease is the probability that if the person has the disease, the test will be positive. The sensitivity is the proportion of true positives of all diseased cases in the population. It is a parameter of the test. High sensitivity is required when early diagnosis and treatment is beneficial, and when the disease is infectious.

**Shot** – 1. a stroke in golf and its result (assumes contact with the ball) 2. the act (past tense) of playing a stroke 3. another way (past tense) to refer to one's score for a round of golf, or tournament

**Slice** - A golf shot that curves hard to the right. Usually this is a miss-hit.

**Specificity** – statistical measure of how well a binary classification test correctly identifies the negative cases, or those cases that do not meet the condition under study. For example, given a medical test that determines if a person has a certain disease, the specificity of the test to the disease is the probability that the test indicates ‘negative’ if the person does not have the disease. That is, the specificity is the proportion of the true negative of all negative cases in the population. It is a parameter of the test. High specificity is important when the treatment or diagnosis is harmful to the patient mentally and / or physically.

**Sway** - generally considered to be an excess of lateral (side to side) body motion in a golf swing

**Swing** – 1. to make a stroke 2. a significant change in the score (as in a scale, or the balance, shifting)
Swing path - (also "path") the direction the clubhead is traveling (generally referred to through the impact area and in relation to the target line).

Swing plane - (also "plane") most easily visualized as the plane that the shaft of the club or the clubhead's arc describes during the swing.

Takeaway - the beginning of the backswing, the initial movement of the club away from the ball and target.

Target line - the line of play, or the line from the ball to the target.

Tee – 1. (also "peg") a small (usually, but not always, wooden) device for setting the ball up above the ground.

Top - 1. (also "dub") when the bottom of the club contacts the ball above its center of gravity and the ball immediately hits the ground. 2. the end of the backswing (where the hands are at their highest).

Torque - Measure of a shaft's resistance to twisting. Low torque shafts twist less and are recommended for stronger players.

Total Weight - Weight of the entire assembled club as expressed in ounces or grams.

Trajectory - The shape and height of a golf ball's flight in relation to its direction.

Under par - (also "subpar") less than or below par.

Validity - major concept in research that has several specific meanings (internal, external, construct, statistical). In a general sense validity refers to the methodological and/or conceptual soundness of research (i.e. in the case of an experiment, a question regarding validity is “Does this experiment really test what it is supposed to test?”).

Vardon grip - (also "overlap grip, overlapping grip") the most common grip in use today, named after historic player Harry Vardon, where the baby finger of the lower hand overlaps and rests on the index finger, or between the index and middle fingers, of the upper hand.

Wood - A golf club used for longer distance than the iron, but is typically more difficult to control. The head used to be made out of wood, but today may be any number of materials.

Wrist cock - (also "wrist break, setting the hands") the procedure of allowing or causing the wrists or hands to cock, set, hinge or fold at the top of the backswing.

X - a score that cannot be determined, as play on a hole was not completed. Example: He took so many swings in the deep bunker without the ball moving that he finally picked his ball up and took an X on the hole.

X factor - the difference in the amount of rotation between the shoulders and the hips.

Yips - nervous twitching in the putting stroke resulting in poor accuracy and a lack of touch.
LITERATURE


Financial support for the publication of this thesis was kindly provided by:

Golf in Egypt, Cairo (Ismail Naguib)

This is Golf, Amsterdam (Martijn van der Meulen)

Aly Naguib

Nayera Shawky

Vanessa and Peter Kersting