UNIVERSITA' degli STUDI di GENOVA

Facoltà di Medicina e Chirurgia

Master in riabilitazione dei disordini muscoloscheletrici

In collaborazione con

LIBERA UNIVERSITA' di BRUSSEL

"Low-back pain in athlete: epidemiology and rehabilitative prospects"

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INDEX.

ABSTRACT

The purpose of this study is to analyze the principal epidemiological data of low-back pain in athletes and to compared results of different rehabilitative protocols.

I searched the articles for this search using Medline database with the following key-words: low-back pain, sport, athlete, rehabilitation and treatment.

I accepted only full texts of Randomized Controlled Trial, Clinical Trial and Systematic Review, English written and published from 1995 to 31/05/2006.

These articles showed that back pain can derive from muscular, disk or bony alterations.

For disk and bony treatment there is evidence about customized protocols based on initial rest and bracing.

Absolutely not to recommend bed rest and further studies are needed to confirm the positive effects of treatment of spondylolysis with external electrical stimulation.

INTRODUCTION

In a professional athlete low-back pain represents a more serious problem than general population. We know that back pain in nonathlete population has a 60% - 90% lifetime incidence [29].

An athlete with low back pain is obliged to reduce or to suspend the participation in training or in challenge, thus to return to previous physical condition it is needed a longer training period.

It is not enough for a sportsman to reduce pain in order to resume training, since an athlete's performance is highly dependent upon the coordinated efforts of multiple structures that could be damaged by a failure treatment of previous injuries.

The repetition of a specific athletic technique is the main aspect of the athlete's activity (tennis player, rowers, golfers and football player…) and often there is also a variable presence of load, interesting lumbar spine, that can damage muscles, intervertebral disks and/or bones.

The studies analyzed in this search underlined the link between back pain and damaged structures and they observed also that the same changes causing back pain in general population are more frequent in athletes.

For example disk degenerations was noted in 75% of athletes compared with 31% of nonathlete[53] while Elliot[16] founded bony and disk degenerations in cricketers in 55% and 65% of cases respectively. McGregor et al.[48] and Caldwell et al[10] studied the relationship between muscular changes and low-back pain in rowers.

So, cause the high damage that is reflected to the athletes, become very important an early diagnosis to distinguish the structures causing back pain.

The observed data suggest that among different instrumental techniques the more effective are SPECT, TAC and scintigraphy, while the same results are not obtained with the use of RX.

I concluded this review comparing the results of the different treatment protocols for each structure that, if damaged, can lead low-back pain.

CRITERIA FOR SELECTION OF ARTICLES

In order to realize this review I used Medline database searching following key words:

1. Low-back pain AND sport,
2. Low back-pain AND athlete,
3. Low-back pain treatment AND athlete,
4. Low-back pain rehabilitation AND sport.

I included in this research only:

1. English written studies.
2. Clinical Trial.
3. Randomized Controlled Trial.
4. Review.
5. Articles published from 1995 to 05/30/2006.

Totally I found 31 free full texts:

Author, title and year	Kind of study and aim	Sample	Method	Conclusion
1. Rabago D, Best TM, Beamsley M, Patterson J. A systematic review of prolotherapy for chronic musculoskeletal pain. Clin J Sport Med. 2005 Sep;15(5):376-80.	Review. The objective of this review is to determine the effectiveness of prolotherapy for treatment of chronic muscolo-skeletal pain.	Database: Medline. All reports involving human subjects treated with PrT were included. The authors obtained the full text of 34 case report, 2 non randomized controlled trials and 6 RCTs.		There' re few high-quality data supporting the use of prolotherapy in sport related soft tissue injuries. Positive results have been reported in non - randomized and randomized controlled trials.

Author, title and year	Kind of study and aim	Sample	Method	Conclusion
2. Shabat S, Gefen T, Nyska M, Folman Y, Gepstein R. The effect of insoles on the incidence and severity of low back pain among workers whose job involves long-distance walking. Eur Spine J. 2005 Aug;14(6):546-50. Epub 2005 Jan 25.	Double blind prospective study. This study examined the effectiveness of insoles constructed in a computerized method to placebo insoles.	60 postmen with low-back pain agreed to participate in this study.	After randomization postmen received either a true insole or a placebo insole for 5 week, and then it was switched to the other insole for the next 5 weeks.	This study demonstrates that the low-back pain decreased significantly after the use of real insoles compared to placebo ones.
3. Barr KP, Griggs M, Cadby T. Lumbar stabilization: core concepts and current literature, Part 1. Am J Phys Med Rehabil. 2005 Jun;84(6):473-80.	Review. The purpose of this article is to review the concepts of lumbar stabilization and how instability can lead to injury and pain.	A Pubmed search of English language articles from 1985 to November 2004 with the key words: physical therapy, LBP, lumbar stability and core strengthening was performed.		Research has shown that with the use of thoughtful exercise program and by imposing low loads to the spine the risk of injury is low and compliance is increased.
4. Hagen KB, Hilde G, Jamtvedt G, Winnem M. Bed rest for acute low-back pain and sciatica. Cochrane Database Syst Rev. 2004 Oct 18; (4)	Cochrane review. To asses the effects of advice to rest in bed for patients with acute LBP or sciatica.	Selection criteria: RCT or CT with quasi-randomization, in any language, where the effectiveness of advice to rest in bed was evaluated.		For people with acute LBP advice to rest in bed is less effective then advice to stay active. For patients with sciatica there's little or not difference between both advices. There's little or no difference in the effect of bed rest compared to exercise, or physiotherapy or 7 days of bed rest compared with 2 or3.

Author, title and year	Kind of study and aim	Sample	Method	Conclusion
5. Folman Y, Wosk J, Shabat S, Gepstein R. Attenuation of spinal transients at heel strike using viscoelastic heel insoles: an in vivo study. Prev Med. 2004 Aug;39(2):351-4.	Clinical trial. The present study was designed to monitor the transient acting on the spine at heel strike and to find out whether said transients are attenuated by viscoelastic heel insoles.	Seven male subjects with similar anthropometric characteristics: mean weight 78 kg (range,74-82), mean height 176 cm (range, 174-180), mean age 29 (range, 25-36). They did not complain of LBP.	The subject walked along a 8 m rigid walkway with a built in high frequency force plate wearing leather-soled shoes, first without modification and then with silicone heel insoles.	Viscoelastic heel insoles significantly attenuate the strain on the spinal column that is caused by walking.
6. Kaufman RL. Popliteal aneurysm as a cause of leg pain in a geriatric patient. J Manipulative Physiol Ther. 2004 Jul-Aug;27(6):e9.	Review- case report. To discuss the management of a patient with unilateral lower extremities for a popliteal aneurysm.	An 85 years old man with a 3 years history of pain in the lower back with irradiation into the right groin, thigh, calf and foot.	After consultation he was referred to a vascular surgeon. The patient received a graft replacement with relief of symptoms.	Resolution of pain and guarded gait was accomplished by a multidisciplinary approach combining conservative care and invasive techniques.
7. Lamoth CJ, Daffertshofer A, Meijer OG, Lorimer Moseley G, Wuisman PI, Beek PJ. Effects of experimentally induced pain and fear of pain on trunk coordination and back muscle activity during walking. Clin Biomech (Bristol, Avon). 2004 Jul;19(6):551-63.	RCT. To examine the effects of experimentally induced pain and fear of pain on trunk coordination and erector spinae EMG activity during gait.	Data were collected from 12 healthy university students with no history of LBP or any other disorder (4 women, 8 men; mean age 21 years, range 18-25 years).	The experiment consisted of 4 conditions: 1. normal walking (control condition) 2-3. subjects walked after i.m. injection of hypertonic saline in the lumbar ES (pain and fear) and isotonic saline (fear, no pain), 4. subjects walked while expecting electric shocks on the skin in the low-back area above tolerance.	Induced pain and fear of pain have subtle effects on erector spinae EMG activity during walking while leaving the global pattern of EMG activity and trunk kinematics unaffected. This suggest that the altered gait observed in LBP patients is probably a complex evolved consequence of a lasting pain.
8. Stasinopoulos D. Treatment of spondylolysis with external electrical stimulation in young athletes: a critical literature review. Br J Sports Med. 2004 Jun;38(3):352-4.	Review. To establish whether external electrical stimulation can decrease pain and heal the defect of the pars interarticularis.	Medline was searched from 1980 to 2003 in the English language using the following subject terms: spondylolysis and non-operative treatment.		Authors can't conclude whether external electrical stimulation is more effective than other conservative interventions or whether it can be used for the treatment of pars defect.

Author, title and year	Kind of study and aim	Sample	Method	Conclusion
9. Helmhout PH, Harts CC, Staal JB, Candel MJ, de Bie RA. Comparison of a high-intensity and a low-intensity lumbar extensor training program as minimal intervention treatment in low back pain: a randomized trial. Eur Spine J. 2004 Oct;13(6):537-47. Epub 2004 Apr 17.	RCT. The main objective was to perform a RCT on the relative efficacy of a high-intensity, progressive resistance training program of the isolated lumbar extensors.	Eighty-one workers in Royal Netherlands Army, with non specific LBP longer than 12 weeks were randomly assigned to either of he two training programs.	The High-intensity training program consisted of a 12-week, progressive resistance training of the isolated lumbar extensor muscle groups. In the Low-intensity training program a non-progressive, low-intensity resistance protocol was used.	High-intensity training of the isolated back extensor was not superior to a non-progressive, low-intensity variant in restoring back function in non-specific low back pain.
10. Bono CM. Low-back pain in athletes. J Bone Joint Surg Am. 2004 Feb;86-A(2):382-96.	Review.	Not specified criteria of selection.		Sacral stress fractures occur almost exclusive in individuals participating in high-level running sports.
11. Caldwell JS, McNair PJ, Williams M. The effects of repetitive motion on lumbar flexion and erector spinae muscle activity in rowers. Clin Biomech (Bristol, Avon). 2003 Oct;18(8):704-11.	Clinical trial. To investigate changes in lumbar flexion together the pattern and level of muscle activity of selected erector spinae during a rowing trial.	The subject group comprised eight female aged between 15-17 years(mean 16.4, SD: 0.7) and eight males aged between 15-16 years (mean 15.9, SD:0.3).	Subjects performed a standardised 2000m rowing test. Adhesive retro reflective surface markers attached to the spinous process of L1 & S1 calculate lumbar flexion. EMG activity was recorded using surface electrodes.	Rowers attain relatively high levels of lumbar flexion during the rowing stroke, and these levels are increased during the course of the rowing trial.
12. Lang E, Liebig K, Kastner S, Neundorfer B, Heuschmann P. Multidisciplinary rehabilitation versus usual care for chronic low back pain in the community: effects on quality of life. Spine J. 2003 Jul-Aug;3(4):270-6.	Clinical trial. To compare the outcome of a multidisciplinary rehabilitation program (MRP) with that of the usual care by independent physician for patients with chronic low back pain.	Physicians recruited 157 patients if they were seeking treatment of pain in the back with possible irradiation into the legs, the pain persisted for at least 3 month without decreasing intensity and no indication for surgical intervention.	In a baseline group, the independent physicians treated the patients with usual care. The MRP team included four sport teachers, one clinical psychologist, three physiotherapists and one physician.	The study concluded that MRP is a promising method to improve health-related quality of life for patients with chronic low-back pain in the community.

Author, title and year	Kind of study and aim	Sample	Method	Conclusion
13. McConnell J. Recalcitrant chronic low back and leg pain--a new theory and different approach to management. Man Ther. 2002 Nov;7(4):183-92.	Review. To examine the influence of a repetitive movement such as walking as a possible causative factor of chronic low-back pain.	Not specified.		Chronic LBP and leg pain require a multifactorial approach
14. Elliott B, Khangure M. Disk degeneration and fast bowling in cricket: an intervention study. Med Sci Sports Exerc. 2002 Nov;34(11):1714-8.	Clinical trial. To identify the relationship between the incidence of lumbar disk degeneration and bowling technique after 3 yrs of educational intervention.	41 cricketers from the Western Australian fast-bowling development squads.	Biomechanical data were collected after a thorough warm up and after each bowler had been anatomically marked for digitizing. Players were filmed laterally and from above by two video camera during each test.	An educational process aimed at reducing mechanical features that have been linked to back injury decreased the incidence and/or progression of lumbar spine disk degeneration.
15. McGregor AH, Anderton L, Gedroyc WM. The trunk muscles of elite oarsmen. Br J Sports Med. 2002 Jun;36(3):214-7.	Clinical trial. To investigate the trunk strength of elite rowers and the impact of LBP to determinate if asymmetries or weakness were present.	Twenty two elite rowers. Thirteen with previous LBP, Five with current LBP and four with no history of LBP.	All subjects were scanned during simulated rowing at level of the L4-5and L5-S1 disc interspace to determine the cross sectional area of the posterior trunk muscles.	This study suggest that LBP in rowers don’t arise as a result of muscle weakness.
16. Gurney B. Leg length discrepancy. Gait Posture. 2002 Apr;15(2):195-206.	Review. To identify the amount of Leg length discrepancy (LLD) necessary to create problems in specific population.	Twenty-four studies that measured the magnitude of LLD necessary to affect subjects using both objective and subjective criteria.		There is still controversy regarding the magnitude of LLD necessary to cause musculoskeletal problems.
17. Lamoth CJ, Meijer OG, Wuisman PI, van Dieen JH, Levin MF, Beek PJ. Pelvis-thorax coordination in the transverse plane during walking in persons with nonspecific low back pain. Spine. 2002 Feb 15;27(4):E92-9.	Clinical trial. To gain insight into the consequences of LBP for gait and to identify clinically useful measures for characterizing the quality of walking in patients with LBP.	Thirty nine patients with non-specific LBP and nineteen healthy participants.	Pelvis and thorax rotations were recorded in the transverse plane by use of an active marker movement registration system.	Patients with non-specific LBP show less adaptation in pelvic-thorax coordination than do healthy person when walking velocity is varied.

Author, title and year	Kind of study and aim	Sample	Method	Conclusion
18. Shah MK, Stewart GW. Sacral stress fractures: an unusual cause of low back pain in an athlete. Spine. 2002 Feb 15;27(4):E104-8.	Review – case report. To document the occurrence of sacral stress fracture in athletes and to recommend it in the differential diagnosis of LBP, especially in runners and volleyball players.	A 16 years old volleyball player. The authors found 29 cases reports of sacral stress fracture in athletes, mainly runners.		Sacral stress fractures are an uncommon cause of LBP in the athlete. Accurate diagnosis is important for the resolution of this disorder.
19. Winett RA, Carpinelli RN. Potential health-related benefits of resistance training. Prev Med. 2001 Nov;33(5):503-13.	Review. To analyze recent research about the effects of resistance training.	Not specified.		Resistance training has favourable impacts on multiple system with few contraindications and also has a very cost-effective preventive intervention.
20. Ogon M, Riedl-Huter C, Sterzinger W, Krismer M, Spratt KF, Wimmer C. Radiologic abnormalities and low back pain in elite skiers. Clin Orthop Relat Res. 2001 Sep;(390):151-62.	Clinical trial. To determine the clinical significance of radiological abnormalities in screening adolescent who had no symptoms for later development of LBP under high performance training.	One hundred twenty children (78 males, 42 females; age range, 14-20 years; mean age, 17 years).	Subjects were evaluated for radiological abnormalities by two independent observers. All athletes were observed prospectively during the subsequent 2 year period for development of LBP under high performance training.	Lumbar radiographs are of limited value for predicting LBP. However, end plate lesions properly classified as severe and located anteriorly were significantly related to later development of LBP in athletes doing high performance training.
21. Sculco AD, Paup DC, Fernhall B, Sculco MJ. Effects of aerobic exercise on low back pain patients in treatment. Spine J. 2001 Mar-Apr;1(2):95-101.	RCT. The purpose of this study was to determine the effects of short and long term aerobic exercise on LBP.	21 man and 14 women with a mean age of 47.68 years (range 30-60).	Subjects were matched stratified into an AE or non exercise control group for a 10 week exercise program.	Low to moderate aerobic exercise appears to improve mood states and work status and reduce the need for physical therapy referrals and pain medication prescriptions for LBP.

Author, title and year	Kind of study and aim	Sample	Method	Conclusion
22. Hildebrandt VH, Bongers PM, Dul J, van Dijk FJ, Kemper HC. The relationship between leisure time, physical activities and musculoskeletal symptoms and disability in worker populations. Int Arch Occup Environ Health. 2000 Nov;73(8):507-18.	Review. To asses the association between leisure time physical activity and muscoloscheletal morbidity, as well as possible interactions with physical activity at work.	A literature search was performed to collect all studies on musculoskeletal disorders in which physical activity was involved as a variable. Next were analyzed questionnaire of 2030 workers on self reported physical activity in leisure time and at work.		Stimulation of leisure time physical activity may constitute one of the means of reducing musculoskeletal morbidity in the working population, in particular in sedentary workers.
23. Babayev M, Lachmann E, Nagler W. The controversy surrounding sacral insufficiency fractures: to ambulate or not to ambulate? Am J Phys Med Rehabil. 2000 Jul-Aug;79(4):404-9.	Review. To analyze the effects of early mobilization in sacral insufficiency fractures (SIF).	Not specified.		Bed rest is not appropriate in the management of SIF. The majority of this fractures are stable and don't require surgical intervention. With good pain control, patients can begin progressive ambulation and the potentially detrimental complications of immobility can be minimized.
24. Sugano A, Nomura T. Influence of water exercise and land stretching on salivary cortisol concentrations and anxiety in chronic low back pain patients. J Physiol Anthropol Appl Human Sci. 2000 Jul;19(4):175-80.	Clinical trial. To asses the influence of a single session water exercise or land stretching on salivary cortisol concentration and anxiety in chronic LBP patients.	Four female and three male, mean age: 61.9 SD:11.8 years, women's height: 148.4cm SD:2.5, men's height: 160cm SD: 7.9, mean weights were 47.9kg SD: 2.5 and 61.2kg SD:1.9 They all suffered from chronic myofascial LBP and their symptoms were low-grade.	Participant were engaged in the water exercise program first, then they participated in the land stretching program on a different day.	The finding of the present study indicated that water exercise and land stretching had the effect of decreasing the level of salivary cortisol and state anxiety.

Author, title and year	Kind of study and aim	Sample	Method	Conclusion
25. Garces GL, Gonzalez-Montoro I, Rasines JL, Santonja F. Early diagnosis of stress fracture of the lumbar spine in athletes. Int Orthop. 1999;23(4):213-5.	Clinical trial. To confirm the value of planar scintigraphy and SPECT in early diagnosis of lumbar stress fractures.	Thirty-three athletes complaining of sport –related lumbar pain with mean age of 21years.	Subjects were all studied by scintigraphy and in 24 of them with single photon emission computerized tomography.	In a patient with persistent LBP and radiographs a SPECT or a planar scintigraphy may provide the stress fracture diagnosis in some patiesnts.
26. Callaghan JP, Patla AE, McGill SM. Low back three-dimensional joint forces, kinematics, and kinetics during walking. Clin Biomech (Bristol, Avon). 1999 Mar;14(3):203-16.	Clinical trial. T examine the three-dimensional low-back loads, spinal motion and muscular activity during gait.	Five male healthy participants. No subjects had history of LBP for a minimum period of 1 year.	Low back joint forces and moments were determined using an anatomically complex three-dimensional model during 3 walking cadences and with free arm swing or restricted arm swing.	Tissue loading during walking appears to be below levels caused by many specific rehabilitation tasks suggesting that walking is a wise choice for general back exercise and rehabilitation programs.
27. Marriott A, Newman NM, Gracovetsky SA, Richards MP, Asselin S. Improving the evaluation of benign low back pain. Spine. 1999 May 15;24(10):952-60.	RCT. To identify factors in the clinical assessment of LBP that indicate when independent diagnostic testing would be useful.	41 subjects with low-back injury and 46 normal healthy subjects.	Subjects were assessed by clinicians and a machine for diagnosis of LBP assessment versus normal backs.	It is possible to improve the accuracy of clinical diagnosis by incorporating a functional evaluation by machine when there is discordance between physical examination findings and reported pain.
28. Majkowski GR, Jovag BW, Taylor BT, Taylor MS, Allison SC, Stetts DM, Clayton RL. The effect of back belt use on isometric lifting force and fatigue of the lumbar paraspinal muscles. Spine. 1998 Oct 1;23(19):2104-9.	Clinical trial. To determine the efficacy of lumbar back belts in minimizing a loss in isometric force production and fatigue of lumbar paraspinal muscles.	Twenty four healthy subjects. Thirteen were man and eleven were women.	Subjects were tested twice: once with and once without a lumbar support belt.	The findings of this study do not support the use of back belts for the purpose of minimizing either lumbar paraspinal muscle fatigue or a loss in isometric lifting force production.

Author, title and year	Kind of study and aim	Sample	Method	Conclusion
29. Bendix AE, Bendix T, Haestrup C, Busch E. A prospective, randomized 5-year follow-up study of functional restoration in chronic low back pain patients. Eur Spine J. 1998;7(2):111-9.	To evaluate the long-term outcome following 5 yrs of participation in an functional restoration (FR) program for patients with chronic, disabling LBP.	238 chronic low back pain patients. Age 18-59 yrs.	Patients with chronic LBP following the FR program were compared with a non treated control group (project A) and with patients on two less intensive treatment programs (project B).	This study shows a positive long term of the Functional Restoration program.
30. Young JL, Press JM, Herring SA. The disc at risk in athletes: perspectives on operative and nonoperative care. Med Sci Sports Exerc. 1997 Jul;29(7 Suppl):S222-32.	Review.	Not specified		There is no proven benefit of prolonged bed rest. Aerobic fitness may be mildly protective against low-back injury and low-back pain.
31. Frost H, Klaber Moffett JA, Moser JS, Fairbank JC. Randomised controlled trial for evaluation of fitness programme for patients with chronic low back pain. BMJ. 1995 Jan 21;310(6973):151-4.	RCT. To evaluate a progressive fitness programme for patients with chronic low back pain.	81 patients with chronic low back pain referred from orthopaedic consultants for physiotherapy.	The patients were randomly allocated to a fitness programme or control group. Both groups were taught specific exercises to carry out at home and referred to a back-school for education in back care. Patients allocated to the fitness class attended eight exercise classes over four weeks in addition to the home programme and backschool.	There is a role for supervised fitness programmes in the management of moderately disabled patients with chronic low back pain.

Table 1: Articles found in Medline database arranged in chronological order.

After reading all articles the following studies were excluded:

Title	Reason of the exclusion
1. Rabago D, Best TM, Beamsley M, Patterson J. A systematic review of prolotherapy for chronic musculoskeletal pain. Clin J Sport Med. 2005 Sep;15(5):376-80.	Not athletic subjects.
2. Shabat S, Gefen T, Nyska M, Folman Y, Gepstein R. The effect of insoles on the incidence and severity of low back pain among workers whose job involves long-distance walking. Eur Spine J. 2005 Aug;14(6):546-50. Epub 2005 Jan 25.	Not pertinent with the search.
5. Folman Y, Wosk J, Shabat S, Gepstein R. Attenuation of spinal transients at heel strike using viscoelastic heel insoles: an in vivo study. Prev Med. 2004 Aug;39(2):351-4.	Not athletic subjects.
6. Kaufman RL. Popliteal aneurysm as a cause of leg pain in a geriatric patient. J Manipulative Physiol Ther. 2004 Jul-Aug;27(6):e9.	Not pertinent for the purpose of the search.
7. Lamoth CJ, Daffertshofer A, Meijer OG, Lorimer Moseley G, Wuisman PI, Beek PJ. Effects of experimentally induced pain and fear of pain on trunk coordination and back muscle activity during walking. Clin Biomech (Bristol, Avon). 2004 Jul;19(6):551-63.	Not athletic subjects.
12. Lang E, Liebig K, Kastner S, Neundorfer B, Heuschmann P. Multidisciplinary rehabilitation versus usual care for chronic low back pain in the community: effects on quality of life. Spine J. 2003 Jul-Aug;3(4):270-6.	Not athletic subjects.
16. Gurney B. Leg length discrepancy. Gait Posture. 2002 Apr;15(2):195-206.	Not pertinent for the purpose of the search.
17. Lamoth CJ, Meijer OG, Wuisman PI, van Dieen JH, Levin MF, Beek PJ. Pelvis-thorax coordination in the transverse plane during walking in persons with nonspecific low back pain. Spine. 2002 Feb 15;27(4):E92-9.	Not athletic subjects.
19. Winett RA, Carpinelli RN. Potential health-related benefits of resistance training. Prev Med. 2001 Nov;33(5):503-13.	Not athletic subjects.
21. **Sculco AD, Paup DC, Fernhall B, Sculco MJ.** Effects of aerobic exercise on low back pain patients in treatment. Spine J. 2001 Mar-Apr;1(2):95-101.	Subjects made a sedentary life.

22. Hildebrandt VH, Bongers PM, Dul J, van Dijk FJ, Kemper HC. The relationship between leisure time, physical activities and musculoskeletal symptoms and disability in worker populations. Int Arch Occup Environ Health. 2000 Nov;73(8):507-18	Not pertinent for the purpose of the search.
23. Babayev M, Lachmann E, Nagler W. The controversy surrounding sacral insufficiency fractures: to ambulate or not to ambulate? Am J Phys Med Rehabil. 2000 Jul-Aug;79(4):404-9.	Not pertinent for the purpose of the search.
24. Sugano A, Nomura T. Influence of water exercise and land stretching on salivary cortisol concentrations and anxiety in chronic low back pain patients. J Physiol Anthropol Appl Human Sci. 2000 Jul;19(4):175-80.	Not athletic subjects.
26. Callaghan JP, Patla AE, McGill SM. Low back three-dimensional joint forces, kinematics, and kinetics during walking. Clin Biomech (Bristol, Avon). 1999 Mar;14(3):203-16.	Not pertinent with the search.
28. Majkowski GR, Jovag BW, Taylor BT, Taylor MS, Allison SC, Stetts DM, Clayton RL. The effect of back belt use on isometric lifting force and fatigue of the lumbar paraspinal muscles. Spine. 1998 Oct 1;23(19):2104-9.	Not athletic subjects.
29. Bendix AE, Bendix T, Haestrup C, Busch E. A prospective, randomized 5-year follow-up study of functional restoration in chronic low back pain patients. Eur Spine J. 1998;7(2):111-9.	Not athletic subjects.

Table 2: excluded articles.

EPIDEMIOLOGICAL DATA OF LOW-BACK PAIN

Back pain is a common reason for lost playing time by competitive athletes, but it is more frequent in some athletes than in other. In comparison with other athletes gymnast appear to be among the most likely to report severe back pain (six on seven elite rhythmic gymnasts report severe back pain over a seven-week period), the wrestlers' rate of low-back pain is 54%, while rates were lower for soccer and tennis player (37%, 32% respectively), furthermore competitive male and female rowers had a 15% and 25% prevalence of low-back pain respectively(8) . Opposite, the overall incidence of low-back pain in skiers was 12.5%, while the general population in the same adolescent age reported a prevalence of low-back pain at least of 16%(52): this is in contrast to the conclusion from some other studies which have suggested an increased incidence of low-back pain among adolescent who are involved in sports activities at a competitive level. Thus, skiing does not seem to be a particular risk factor for low-back pain.

The articles I found lead to distinguish among muscular, disk-related and bony possible causes(63, 8, 10, 17, 48, 61, 52, 22, 73) of low-back pain.

MUSCULAR CAUSE OF LOW-BACK PAIN

A study of McGregor et al.[48] analyzed measures of cross sectional area of the muscles acting directly on the lumbar spine in elite rowers during simulated rowing.

Competitive rowing is an endurance sport associated with long hours of intensive training both on and off the water.

As seen, low-back pain is a considerable problem in the rowing world. What is unknown it is why such injuries occur.

Rowing is an asymmetric activity which involves loading the back in a rotated and flexed position, factors already identified in back pain. Repetition of an asymmetric activity can lead the development of muscle asymmetry and injury, if not addressed by appropriate training methods.

Another factor that might influence the possibility of a low-back pain injury in rowers is the amount of lumbar flexion that occurs during the rowing stroke[10].

McGregor et al.[48] examined twenty two elite rowers with a mean age of 22.6 (4.3 SD).

Thirteen subjects reported previous low-back pain which had required non surgical intervention and had resulted in time off training, five subjects reported current low-back pain preventing full training and four had no history of low back pain.

Subjects were scanned during simulated rowing in an open magnetic resonance imaging scanner. In each simulated rowing position, axial scans were obtained at the level of the L4-L5 and L5-S1 disc interspace to determine the cross sectional area of the posterior trunk muscles.

The imaging protocol showed perfectly the lumbar spine muscles: erector spinae, multifidus and ileopsoas.

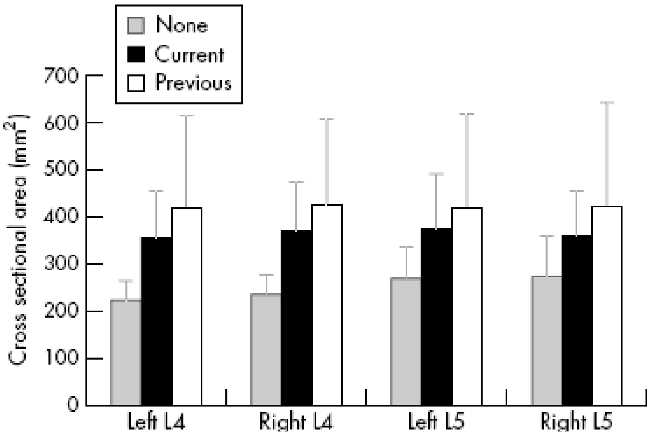

Figure 1: Cross sectional area (mm^2) of the multifidus muscle in rowers with no, current or previous low-back pain.

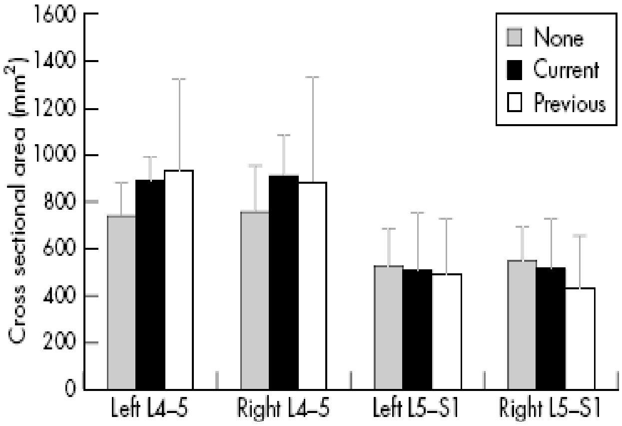

Figure 2: Cross sectional area (mm^2) of the erector spinae muscle group in rowers with no, current or previous low-back pain.

Comparison of these three groups of rower produced some unexpected results and suggest that rowers with back pain have larger back muscles and, thus, greater strength than rowers without low-back pain. It is not known if this observation is a cause or an effect of back pain; the increased strength in the spinal muscles, how suggests the author, may be a consequence of poor technique: the rowers with back pain predominantly using their backs to generate force enduring the stroke rather than their leg. Other authors have speculated that it is fatigue not strength of the back muscles that is important but this was not addressed in this study.

However, these findings suggest that low-back pain in rowers don’t arise as a result of muscle weakness.

The amount of lumbar flexion occurring during the rowing stroke has been suggested as another factor that might influence the possibility of a lower back injury and this hypothesis has been investigated by Caldwell et al.[10].

Eight females and eight males competitive rowers, aged between 15 and 17 years and without current history of low-back pain, performed a standardised

2000m rowing test which approximated the intensity, duration and racing strategy of a competitive rowing race. Adhesive retro-reflective surface markers were attached to the spinous process of L5 - S1 and were recorded three consecutive rowing strokes at 20%, 60%, 95% time points of the rowing trial while EMG for spinal extensor was recorded using surface electrodes in the same points.

Within the drive phase of the rowing stroke two points were associated with maximum lumbar flexion and high compressive forces on the lumbar spine: 10% and 60%.

Results shown that the mean total range of motion for male and female was 52° and 53° respectively, but also shown that at 20%, 60%, 95% of the trial, lumbar flexion remained relatively constant for the first 60% of the drive phase and then between 60% and 100% of the drive phase lumbar flexion decreased.

Lumbar flexion (% total range of lumbar flexion) and EMG activity (%MVC) for the multifidus, illiocostalis lumborum and longissimus thoracis muscles across the duration (20%, 60%, and 95%) of the rowing trial

Trial time	20%		60%		95%	
Drive time	10%	60%	10%	60%	10%	60%
Flexion	80 (12)	74 (15)	82 (11)	80 (11)	87 (9.6)	89 (6.7)
Multifidus	16 (9)	55 (16)	24 (13)	62 (23)	32 (13)	76 (15)
Illiocostalis	16 (12)	55 (21)	21 (16)	65 (23)	26 (17)	80 (18)
Longissimus	15 (7)	46 (13)	20 (8)	55 (21)	26 (9)	66 (17)

Data are means and standard deviations.

Table 3.

Data from EMG activity of multifidus, ileocostalis lumborum and longissimus thoracis reported for each muscle that muscular activity progressively increased to maximum values at the mid region of the drive phase and then subside to values similar to those that were recorded at initial stage.

Furthermore, EMG activity significantly increased ($p<0.05$) across the three stages of the rowing trial for each of the two drive points (10% and 60%) examined.

The percentage of lumbar flexion used during motion has been shown to influence the stress placed on lumbar intervertebral soft tissue[2].

This study also revealed that flexion increased over the period of the rowing trial from 75% to 90% of the maximum range of motion.

Adams and Dolan[1] have reported that 100% flexion in vivo is approximately 70% of the range of motion allowed by the ligament before they become damaged in vitro.

In this respect the muscles of erector spinae are thought to limit the in vivo range o motion and hence provide some protection to the disc and ligamentous structures.

Furthermore, it is necessary to consider that muscle fatigue of the erector spinae may contribute to increased flexion of the lumbar spine; in the present study evidence of muscle fatigue was demonstrated by a decrease in the median frequency of EMG of all muscles examined.

Thus Caldwell[10] concluded that level of lumbar flexion increased during the course of the trial and found indirect evidence of muscle fatigue in erector spinae muscles that may in part be responsible for the increased levels of lumbar flexion observed.

Previous work[71] demonstrated that different back extensor muscles alternated their level of activity during a fatiguing task and these authors suggested this may be a strategy to reduce effects of fatigue in any one back extensor.

Others have studied the impact of flexibility on low-back pain.

The potential of injury is increased when consideration is given to the repetitive nature of the rowing stroke because cyclic flexion-extension motion combined with relatively low compressive force has been noted to be the most cause of disc herniation[47].

Kujala et al.[37] prospectively examined lumbar flexion in a group of adolescent athletes and non-athletes control.

He found no difference between male and hockey soccer players and controls, but found that female athlete (gymnast and figure skaters) had a greater range of motion of the low lumbar levels than did female control.

Sward et al(66) evaluated lumbar mobility of 116 top male Swedish athletes in relation to back pain. While wrestlers and gymnasts were more flexible and soccer players were less flexible, there was no correlation between spinal flexibility and back pain

DISK RELATED LOW-BACK PAIN

Participation in sports appear to be a risk factor for the development of disk degeneration; every sport places unique demands on lumbar spine and, in turn, the intervertebral disk. Large forces are produced in the disk during various athletic manoeuvres. A golf swing, a primarily torsional activity, produces 6100 and 7500 N of compressive force across the L3-L4 disc in amateur and professional players, respectively. Gatt et al.(23) measured forces in the L4-L5 motion segment during blocking manoeuvres in five football linemen. The average peak compressive load was >8600 N, with an average peak sagittal shear force of 3300N. These data suggest that football lineman are at risk for routine repetitive disk microtrauma. Capozzo et al.(12) found that, when a person performed half-squat exercises with weights approximately 1.6 times body weight, compressive loads across L3-L4 motion segment were about ten times body weight.

These studies demonstrated that disc degeneration appear to be influenced by the type and intensity of the sport. Sward et al.(68) compared radiographic changes in the lumbar spines of elite gymnasts with those in a randomly selected control group. Evidence of degenerative changes was noted in 75% (eighteen) of the twenty four athletes compared with 31% (five) of the sixteen non athletes. Eleven gymnasts demonstrated severe disk degeneration, whereas none of the non athletes did (the exact criteria for distinguishing severe from non severe findings were not described).

Ong et al.(53) studied a group of thirty one Olympic athletes who presented with low-back pain and/or sciatica. MRI demonstrated that the disk signal progressively decreased from cephalic to caudal direction, with L5 and S1 being the most commonly affected level (in 35% =11 of the athletes). Disc bulges were detected in 58% (eighteen) of the thirty one participants at the L5-S1 level.

So, comparing their data with previously published rates of abnormalities in non athletes, the authors concluded that degeneration was more common in Olympic athletes.

While degenerative findings were most common in weight lifters, this group did not have a higher rate of back pain.

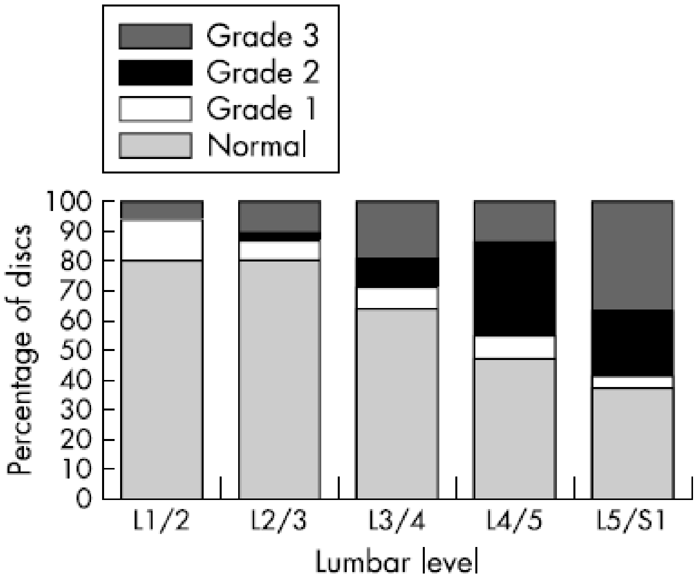

Table 4: Signal intensity of lumbar discs. Grade 1: mildly reduced; grade 2: moderately reduced; grade 3: severely reduced.

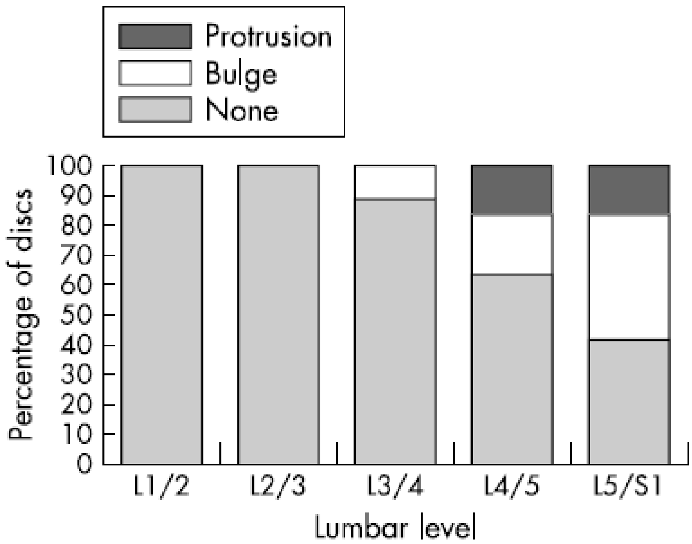

Table 5: Displacement of lumbar disks.

Bartolozzi et al.[5] found that, of nineteen Italian volleyball players who used proper technique and did not overtrain, 21% (four) had degenerative changes, whereas, of twenty-six who used improper technique and overtrained, sixteen (62%) had such changes.

Elliot and Khangure(17) studied the relationship between the incidence of lumbar disk degeneration and bowling technique after 3 years of educational intervention.

Burnett et al.(9) and Elliot et al.(16) in their study founded that the incidence of disk degeneration was significantly related to transverse plane counter-rotation of the shoulder alignment (line joining the acromion processes) by greater than 20° in the bowling action. Furthermore bowlers who delivered the ball from a greater relative release height were more likely to sustain a back injury.

A longitudinal study by Portus(56) of elite fast bowlers reported a mean transverse plane counter-rotation of the shoulder alignment of 41°. This was the only technique characteristic to be statistically linked to an increased incidence of lumbar stress fractures.

Elliot and Khangure(17) selected two groups of cricketers from the Western Australian fast-bowling development squads: first group comprised twenty four male fast bowlers of mean age 13.4 years attending at least three of the four yearly testing session between 1997 and 2000, the second group comprised seventeen male of mean age (in 1998) of 13.2 years attending a minimum of two of three yearly testing session between 1998 and 2000. At the time of testing, no bowler had any knowledge of abnormalities radiological features and all were bowling without pain.

After as many practice trials as required, subjects bowled three maximum velocity trials at a wicket within a biomechanics laboratory. MRI scans were all recorded after bowling assessment. The highest velocity trial was selected for analysis and the scans allowed each bowler to be placed into one of two categories (normal or abnormal radiological appearance of the disk, suck as a disk degeneration or bulging).

If degeneration was evident, then the previous scan was reviewed to asses whether progression had occurred over the 1-year period. No control group was employed, as there is evidence showing that making no changes in shoulder counter-rotation by mixed action bowlers will lead to concomitant increases in disk degeneration with no intervention strategy. This study sought to quantify changes in the incidence of lumbar disk degeneration in young bowlers over a 4 years period; during this time all fast bowlers were counselled as to the possible causes of back injury through an annual seminar and a series of coaching session (6 per year) aimed specifically at reducing the level of shoulder alignment counter-rotation. The results of this search showed a degeneration level of 24.4% for the youngest group of bowlers.

The 35.4° transverse plane counter-rotation of the shoulder at the baseline of the study was similar to levels that have been linked with lumbar disk abnormalities.

The greatest increase in the occurrence of degeneration is seen between years 1-2, showing that the intervention needed more than 1 year of coaching to be available.

Some studies have suggested an association between specific imaging findings and the likelihood of back pain. Lundin et al.(42) prospectively examined initial and ten year follow-up radiographs of a group of athletes. The radiographic finding that most strongly correlated with low-back pain was decreased disc-space height, regardless of whether it was detected on the initial or follow-up examination.

Furthermore, the greater the number of levels involved, the more likely the athlete was to have had low-back pain. Sward et al.(68) found that decreased signal intensity within the disk on magnetic resonance imaging correlated with low-back pain in both athletes and non athletes.

Videman et al.[72] reported that former elite athletes with a history of at least monthly low-back pain had significantly high scores for disc degeneration on MRI than did those who had pain less frequently than twice a year.

Despite a big number of studies, the exact correlation between a degenerated intervertebral disk and low-back pain remains elusive. Willis et al.[36] demonstrated that stress within the annulus can produce tears within in: circumferential tears, representing delamination of the fibres within the tough outer ring, occur first, but with continued stress these can progress to radial tears.

Next nuclear desiccation and loss of proteoglycan ensue and a diminished capacity of the disk to sustain load places greater demands on the posterior facet joints, causing degeneration of the articular surfaces.

It has been proposed that advance degenerative changes, such as osteophyte formation in both the disc and the facets, are an attempt at autostabilization. Various components of the motion segment have been implicated as potential pain generators. Nociceptive micro innervation of the posterior aspect of the annulus, anterior aspect of the annulus and facet joints has been characterized in anatomical and histological studies. Reproduction of a patient's typical low-back pain with discography suggests that leakage of intradiscal fluid or anular distention is involved in the production of back pain . Willis et al. concluded that despite ever increasing amounts of information, some limitations of diagnostic abilities related to an understanding of disk degeneration and disc degeneration remain.

BONE DISEASES AND LOW-BACK PAIN

Most studies previously analyzed, confirmed that sport performed at a competitive level may cause low-back pain; elite sport has reached an extremely high level in most classic disciplines, thus it is important to start a competitive career at a young age if an international level is an objective. Consequently the age level of athletes enrolled in elite sports has decreased and to protect children and adolescents from later health problems it has become common practice to do a medical evaluation before a career in elite sports(52). Screening of risk factor for development of low-back pain often include anterior-posterior (AP) and lateral radiographs but a lot of studies questioned the value of preplacement radiographic screening for predicting low-back pain; retrospectice studies conducted on preemployment radiographic assessment of the lumbar spine in adults failed to identify any developmental or degenerative radiological change with predictive value and indicated no reduced incidence of low-back pain by use of preemployment radiological screening(24).

Ogon et al.(52) analyzed the clinical significance of radiological abnormalities in screening adolescents elite skiers who had no symptoms for later development of low-back pain under high performance training. One hundred twenty children: 78 males and 42 females with the mean age of 17 years were included in this study; no subjects had any symptoms of the lumbar spine at the clinical evaluation (physical examination and plain radiographs of the thoracolumbar and lumbar spine) before enrolment in the school and no history of low back pain was revealed. AP and lateral view radiographs were taken with the subjects standing and, according to their location, abnormalities of the end plate were assorted in three group: anterior lesions (involving the anterior vertebral edge), Schmorl' s node (not involving the anterior vertebral edge) and posterior lesions (lesions in the posterior third).

The authors compared, for each radiological abnormality, the incidence of low-back pain among students with the particular abnormality with the incidence of low-back pain among students without this abnormality.

The end plates for the T12, L1, L2, L3, L4 and L5 vertebrae (12 end plates of 120 athletes = 1440 end plates) were evaluated by a radiologist and an orthopaedic surgeon.

Lesions were found in 217 end plates (15%):

- 175 anterior lesions,
- 31 Schmorl’s nodes,
- 11 posterior lesions.

More anterior lesions were found in the upper lumbar spine with a peak at the second lumbar vertebra (N:33 = 27.5%). In the lower part of the lumbar spine only a few lesions were found. The distribution between the upper and lower end plates was homogenous.

During the subsequent 2 years 15 students experienced low-back pain and 63 had no radiographic change. Of the 63 students without radiographic changes, 5 (8%) reported low-back pain like 10 of the 57 (18%) students with radiographic changes. Fifty four athletes (45%) had anterior lesions: 25 had severe lesions and 29 had moderate lesions.

Of the students with severe anterior lesions 8 (32%) experienced low-back pain compared with 1 (3.5%) of the students with no anterior lesions. It is possible to state that students with severe anterior lesions were significantly more likely to have back pain than students with moderate or no anterior lesions.

About Schmorl’s nodes 19 students were affected and 4 (21%) experienced low-back pain compared with 11 of 101 (11%) who did not have: so the presence of Schmorl’s nodes don’t increase risk of low-back pain.

Seven students (6%) had moderate posterior lesions and only one student experienced low-back pain compared with 24 of 113 (21%) who did not have a posterior lesions, so students with posterior lesions were not more likely to have low-back pain.

End Plate Lesion	Number*	% Low Back Pain	Odds Ratio	p Value
Severe anterior lesion	25	32	3.8	0.04
Moderate anterior lesion	29	3	0.3	0.27
Schmorl's node	19	21	1.8	0.44
Posterior lesion	7	14	1.7	0.67

* = students with the particular end plate lesion.

Table 6: LBP among adolescent elite skiers with different end plate lesions.

The impact of end plate abnormalities on the development of low-back pain is a matter of controversy. Sward et al.(67) investigated back pain and radiological changes in 142 elite athletes involved in wrestling, gymnastic, soccer and tennis and reported a significant correlation between Schmorl's node (anterior, apophyseal and non apophyseal) and back pain. Greene et al.(26) found an association between the onset of low-back pain and strenuous activity in adolescent with invertebral disk herniation, disk space narrowing and minimal wedge deformity primarily located at the dorsolumbar junction. Opposite, several studies don't found correlation between most radiological changes in the spine and low-back pain. Harreby et al.(30) found radiological abnormalities (mainly Scheuermann changes) in 13% of 640 school children. However their results indicated no positive correlation between radiological changes in the spine and low-back pain in the adolescent or in adults. Frymoyer et al.(21) reported a similar frequency of Schmorl's nodes between groups of adults with severe, with moderate or with no low-back pain.

The results of the Ogon's study(52) indicate that severe lesions have to be distinguished from moderate lesions and also emphasize the clinical significance of this radiological classification. Furthermore this study showed that lumbar radiographs are limited value for predicting low-back pain according to the findings of Garcés et al.(22) who studied the value of planar scintigraphy and SPECT in early diagnosis of lumbar stress fractures in thirty-three athletes complaining of back pain of more than one months' duration.

The mean age of patients was 21 years and the distribution by sport was:

14 wrestlers, 3 basketball player, 3 tennis player and 11 practiced other sports.

The criteria of inclusion in the study were: presence of lumbar pain of unknown origin for more than 1 month not alleviated by medical treatment, AP, lateral and oblique radiographic enhancement not showing any abnormalities, and no previous lumbar surgery. All athletes were studied by scintigraphy and 24 of them a single photon emission computerized tomography (SPECT).

Planar scintigraphy suggested stress fractures, showing increased radio tracer uptake, in 17 of the 33 cases (51.5%) and a total of 28 affected vertebrae were detected in the 17 patients with raised scintigraphy uptake; this was distributed into: 2 at L2, 7 at L3, 7 at L4 and 12 at L5. Seven of the seventeen patients had more than one vertebrae with increased tracer activity.

Increased uptake of the radio tracer was detected in 16 of 24 patients studied with SPECT (66.6). In all the cases in which planar scintigraphy was positive and SPECT was also carried out, SPECT showed increased uptake[22]. However of the 16 cases in which planar scintigraphy was normal, SPECT was positive in eight.

The author concluded that in a patient with persistent low-back pain and radiographs without pathological abnormalities a SPECT may provide the stress fracture diagnosis in some patients. If SPECT is not available but a planar scintigraphy results positive a SPECT will not be necessary.

However in cases of normal planar scintigraphic findings a stress fracture may can be ruled out until the SPECT is performed.

Shah et al.[61] reviewed all medical records, radiological tests and related literature to document the occurrence of sacral stress fractures in athletes and to recommend it in the differential diagnosis of low-back pain.

They found 17 patients with sacroiliac joint tenderness and 7 with buttock tenderness; most of them had full range of motion of their backs and lower extremities. The right side of the sacrum was affected more frequently than was the left (17 right, 8 left).

The cause of sacral stress fracture is controversial. One possible explanation is concentration of stresses from vertical body forces that become dissipated from the spine to the sacrum and sacral ala.

Athletes endure repetitive loading on the sacrum, which places abnormal stress on normal bone[44] that can produce this fracture, especially in the elderly . A second reported cause is progressive insufficiency of the supporting muscles. This process may lead to transfer of loading forces directly to the bone without absorption of some energy by the muscles.

Concluding, another common cause of low-back pain in athlete is spondylolysis which has been reported to range from 13% to 47% among adolescent athletes[63]. Usually are involved the L5 and occasionally the L4 vertebrae. The prevalence of spondylolysis in athletes is variable and some sport appear to be associated with a higher prevalence. In a study of 3132 competitive athletes, Rossi and Dragoni[58] reported a rate of 43% in divers, 30% in wrestlers and 23% in weight lifters. Soler and Calderon[62] documented a prevalence of 27% in throwing athletes, 17% in gymnasts and 17% in rowers. Micheli and Wood[49], studying 100 adolescent athletes and 100 adult athletes with back pain, found that the adolescents had a higher rate of spondylolysis (47%) than did adults (5%). In some of the earliest reports of spondylolysis in athletes, young female gymnasts had been identified to be at particular risk.

The exact etiology of spondylolysis is still unclear; it has been described as hereditary or acquired as the result of repetitive stress and fatigue of the lower segment, leading to a stress reaction and subsequent failure. The latter hypotesis has led to the postulate that lumbar lordosis, such as is seen in Scheurmann's kyphosis, and sports that demand repetitive hyperextension and rotation of the lumbar spine, such as divers, wrestling, volleyball, gymnastics, football and weightlifting, are associated with higher incidences of spondylolysis(63).

OLD AND NEW REHABILITATIVE EVIDENCE BASED STRATEGIES

For the athlete the distinction between absence of *symptoms* and absence of *dysfunction* is particularly important. Although pain is generally what prompts an athlete to seek medical care, an athlete's performance can suffer in the absence of pain but in the presence of subtle biomechanical flaws and maladjustment resulting from inadequate training regimens or failure to rehabilitative previous injuries.

This is particularly important for athletes such as baseball pitchers, tennis player and quarterbacks whose performance are highly dependent upon the kinematic chain(73), thus whatever rehabilitative plan a physical therapist projects, he has always to remember this distinction.

REHABILITATIVE PROGRAMS FOR MUSCULAR LOW-BACK PAIN

Various rehabilitation protocols have been suggested specifically for low-back pain.

In a systematic review Hagen et al.[28] assessed the effects of advice to rest in bed for patients with acute low-back pain or sciatica.

They compared advice to rest in back with other treatments and obtained the following results:

- <u>Bed rest versus stay active for acute LBP</u>: high quality evidence on pain, on functional status and on sick leave in favour of staying active;
- <u>Bed rest versus stay active for sciatica</u>: high quality evidence that advice to rest in bed has little or no effect on pain, on functional status and on the length of sick leave compared to advice to stay active;
- <u>Bed rest versus other treatments for acute LBP</u>: high quality evidence that advice to rest in bad has little or no effect on pain, functional status or length of sick leave compared to exercises;
- <u>Bed rest versus other treatments for sciatica</u>: moderate quality evidence of little or no difference in pain intensity between advice to rest in bed and physiotherapy, and small effects in favour of physiotherapy for functional status;
- <u>Short bed rest versus longer bed rest for acute LBP</u>: no significant differences in pain intensity between three and seven days of bed rest;
- <u>Short bed rest versus longer bed rest for sciatica</u>: moderate quality evidence of little or no differences in pain intensity between short and long bed rest.

Authors concluded that advice to rest in bed is less effective than advice to stay active for people with acute low-back pain, while for patients with sciatica there is little or no difference between bed rest and the options analyzed and further research is unlikely to change this results.

Hopkins and White(32) described a three cycle level system for rehabilitation after athletic low-back injuries and each cycle differs in the relative degrees of rest, therapy and time until return to play:

- Cycle 1A: immediate return to full activity; game and practise are not missed;
- Cycle 1B: games and body contact are prohibited, practice is reduced by 75% (duration, intensity and frequency), nonsteroidal anti-inflammatory drugs, physical therapy optional, back to competition in four days;
- Cycle 1C: games and body contact are prohibited, practice is reduced by 50%, nonsteroidal anti-inflammatory drugs, physical therapy optional, advance to cycle B in four days;
- Cycle 2: games and practice are prohibited, nonsteroidal anti-inflammatory drugs, two days of bed rest followed by physical therapy for abdominal strengthening for five days and advance to cycle 1;
- Cycle 3: games and practice are prohibited, nonsteroidal anti-inflammatory drugs, two days of bed rest followed by physical therapy for abdominal and paraspinal strengthening stationary bicycling, walking or swimming.

Helmhout et al.(30) compared the effects of a high intensity and low intensity lumbar extensor training program on 81 military and civilian employees in Royal Nethrlands Army (RNLA). All participants were randomly assigned to a high intensity training (HIT) or a low intensity training group (LIT).

A progressive resistance training of isolated lumbar extensor muscle group was performed for 12 week by HIT group;

this program included 10 training session (2 days/week in week 1 - 2 and 1 day/week in week 3-12) and the initial load was set at approximately 35% of the maximal isometric back extension strength of the participants. The goal of every training session was to perform 15 to 20 repetitions (weeks 1-2) or 10 to 15 repetitions (week 3-12) on the lower back machine.

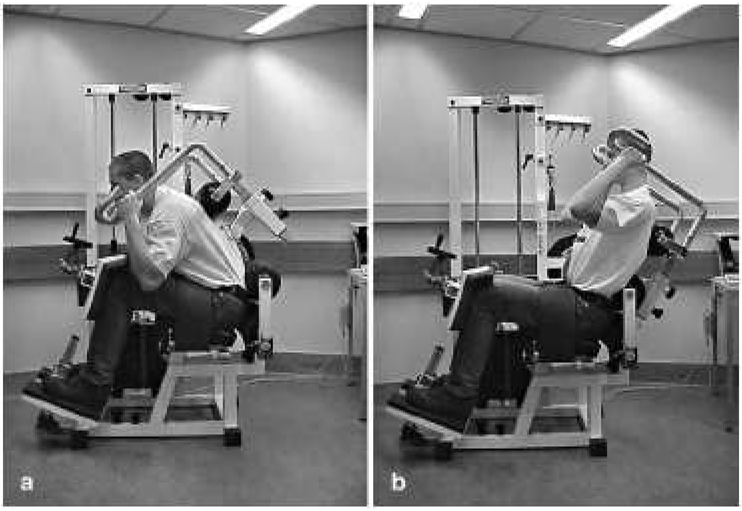

Fig 3: modified lower back test and training machine with the subject on the left in flexed position and on the right in extended position.

If the participant was able to perform a higher number of repetitions, the subsequent training load was loaded by 2.5kg but if the participants was unable to perform the minimal number of repetition a 2.5kg weight was eliminated.

In the LIT program the initial training load was set at no higher than 20% of the maximal isometric strength and the goal of every training session was to perform 15 (first and second week after each test) or 29 (third and fourth week after each test).

The results showed that both training programs led to comparable improvements in all outcome measures at 1, 2, 3, 6 and 9 months of follow-up except for mean isometric strength in according with a systematic review of Van Tulder et al.(70) that concluded that strengthening exercises are not more effective than other type of exercises (evidence level 1).

The strength gaining effect of the HIT program exceeds the training period by approximately another 3 months and it could be explained by the high percentage of patients who continued to participate in exercise training in the follow up period.

Moreover a higher initial back strength leads to a higher strength increase in time.

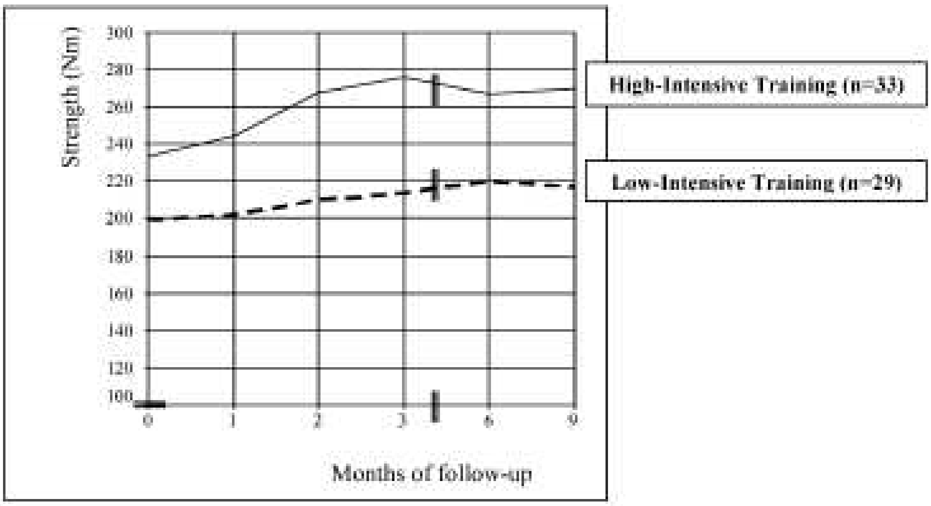

Table 7: Strength development in participants from both intervention group who had a complete 9 month follow-up

To prevent muscular injuries that could lead low-back pain athletes are usually performs warm-up exercise but despite the widespread use and acceptance there are few data demonstrating that warm-up exercises can decrease the prevalence of low-back pain or the risk of injury in athletes.

Green et al.[25] measured range of motion in twenty six volleyball players prior to activity, immediately after a standardized warm-up regimen and after a standardized warm-up followed by thirty minutes of rest. Authors observed that the lumbar spines were stiffer in extension after rest than they were immediately after warm-up.

These data suggest that bench rest after warm-up exercises can have a detrimental effect on lumbar flexibility, but also suggest that the ability of warm-up to prevent injury might be due to another mechanism.

Kujala et al.[38] noticed that not only specifically targeted training did not increase maximal lumbar extension in adolescent athletes, but also if too aggressive it can stress structures such as inter-vertebral disc or pars inter-articularis. Opposite, Kibler et Chandler[35] found a specific conditioning program to be effective in increasing the lumbar range of motion in fifty nine tennis player. Resuming all these studies indicated that with proper training lumbar flexibility in competitive athletes reaches a plateau that should be maintained by regular stretching, but attempts to push beyond that point in an effort to enhance performance might be detrimental.

OPERATIVE AND NONOPERATIVE TREATMENT OF DISCOGENIC LBP

A lot of rehabilitative protocols have been suggested for the conservative treatment of discogenic low-back pain.

Cooke and Lutz(13) detailed a five stage rehabilitation protocol:

1. early protected mobilization: brief period of rest followed by various therapeutic modalities;
2. dynamic spinal stabilization: co-contraction exercises of the abdominal and lumbar extensor muscles to stabilize the injured motion segments and isometric exercises to retrain muscles to maintain a mechanically neutral position;
3. strengthening of the lumbar muscles;
4. the athlete returns to sport activity: plyometric exercises are recommended in this stage;
5. institution of a maintenance program with regular home and warm-up exercises.

Young et al.(73) emphasized the importance of active participation of the physical therapist in continually modifying the therapeutic regimen as the athlete progresses and underlined that therapy goals are pain reduction and decreasing the length of symptomatic episodes that can be reached by targeting abnormal skeletal shifts and posture, reducing abnormally high muscle tone in spastic regions and reinforcing a comfortable body position which is more often lumbar extension in patients with discogenic pain.

Young et al.(73) demonstrated that a customized approach appears to be more effective, thus therapists with a broad range of skills in addressing low-back pain have a greater likelihood of helping patients who have different problems.

To obtain a rapid progression is really important the managing of pain.

Young’s review[73] also noticed that aerobic fitness may be mildly protective against low-back injury and LBP because acute low-back pain results in reduction of physical activity which leads to reduction of aerobic fitness.

This problem may have significant consequences if it occurs on a recurrent basis. For this reason it is important that aerobic exercises be incorporated in the low-back pain rehabilitation as early as possible.

Elliot and Khangure[17] in their study obtained a reduction of incidence and progression of disk degeneration of 33%; the greatest increase in the occurrence of degeneration is seen between years 1-2, showing that the intervention needed more than one year of coaching to be effective. The level of shoulder counter-rotation at 1 year significantly reduced 24.8° and 21.3° after 2 and 3 year of intervention respectively.

Operative treatment of discogenetic low-back pain currently consist of various methods of fusion; a review of the available literature suggests that interbody fusion techniques result in higher fusion rates and possibility better clinical outcomes than do postero-lateral fusions. Thus, currently, most surgeon prefer an interbody technique rather than a postero-lateral fusion alone. This reflects an increasingly popular belief that the disk itself is the main pain generator[8].

I haven’t found information concerning the optimal time at which the athlete should return to sports activity after lumbar fusion; however the athlete should no return until there is radiographic evidence of a solid fusion, complete or nearly complete resolution of pain and restoration of competitive level measured functional parameters such as strength, flexibility and endurance.

TREATMENT OF BONE-RELATED LOW-BACK PAIN

Sacral stress fracture and spondylolysis are the two causes of low-back pain previously analyzed.

A wide range of conservative interventions has been used for the treatment of spondylolysis.

Several studies have shown that patients with spondylolysis may be successfully treated conservatively, but these articles don't specifies which treatment is the most effective. A lot of rehabilitative projects have been developed: activity restriction(55), anti lordotic bracing(7), exercise (abdominal stretching, hamstring stretching, pelvic tilt and stabilizing exercises of the muscle that surround the spine) (15).

The role and best type of external immobilization continue to be debated. Most authors have agreed that athletes can return to play when they are pain-free, regardless of whether there is radiographic evidence of pars healing.

Jackson et al.(33) treated a group of young athletes with pars stress reactions by limiting movements and activities that aggravated pain. This treatment was individualized to each athlete, and none discontinued playing sports. The treatment included a short period of initial bed rest. The authors reported using a form-fitting brace intended to limit hyperextension of the lumbar spine, but they did not report the duration of use or the criteria for discontinuation of such treatment.

Blanda et al.(7) reported the results of nonoperative care of sixty-two athletes with symptomatic spondylolysis. Defects were documented by radiographs or by bone scans. Athletes were treated with restriction of activity and bracing (to maintain lumbar lordosis) for two to six months. No sports or exercise was permitted during the entire treatment period. Fifty-two patients (84%) were reported to have an excellent result; eight (13%), a good result; and two (3%), a fair result.

The rate of radiographic healing (independent of clinical outcome) was higher for unilateral defects (18 of 23) than bilateral defects (3 of 37).

Ninety eight per cent of patients had either a good or an excellent result with regard to pain relief after bracing. The average duration of follow-up was 4.2 years, with a minimum of two years. The authors concluded that lordotic bracing was an effective treatment.

Steiner and Micheli(64) used a modified, overlapping brace to treat sixty-seven young athletes with symptomatic spondylolysis or grade-I spondylolisthesis. The antilordotic brace was designed to hold the lumbar spine in relative. Seventy-eight percent (52%) of the patients demonstrated a good or excellent result with no pain and returned to full sports activity. Nine (13%) had continued mild pain, and six (9%) underwent a posterolateral fusion for pain relief. The average duration of follow-up was 2.5 years.

Stasinopoulos(63) analyzed the effect of external electrical stimulation on treatment of spondylolysis in young athletes. External electrical stimulation was used in adolescent athletes, but in a different ways in two articles.

Pettine et al.(54) used it from the beginning of the treatment in combination with bracing and restriction of activities, whereas Fellander-Tsai and Micheli(18) used it when the traditional methods failed; they showed that the pars defects healed as a result of the external electrical stimulation, as the patients had not been advised to restrict their activities. This findings shows that it can be used successfully eve if patients have not been advised to restrict their activities.

Mooney(50) reported the efficacy of external electrical stimulation as a supplement to bone grafting in spinal fusion and the rate of lumbar spinal fusion improved significantly compared with control group.

D'Hemecourt et al.(14) evaluated the results of antilordotic brace treatment in seventy-three young athletes (33 with negative RX, but positive on SPECT) with spondylolysis or grade-I spondylolisthesis.

Patients wore a brace for twenty-three hours per day for six months followed by a weaning period of several months.

They also performed a physical therapy program with a focus on flexion exercises.

Athletes returned to sports as early as four to six weeks after the initiation of treatment if they had no pain with extension on physical examination, had worn the brace full-time, and remained pain-free. Fifty-six (77%) of the athletes having a good or excellent result.

Sys et al.[69] documented the results of nonoperative treatment of twenty-eight elite athletes (12 to 27 years) with a pars lesion.

All subjects had negative findings on plain radiographs but bone scans, SPECT and TC confirmed the diagnosis.

Patients wore brace for a mean of sixteen weeks and subsequent follow-up for an average of thirteen months. A second computed tomography scan was made at the time of final follow-up to assess healing of the defect.

The authors classified the results among: unilateral, bilateral or “pseudo-bilateral” defect (as asymmetrical signal within the pars bilaterally, indicating a confirmed unilateral lesion with a questionable or developing contralateral one.)

All eleven unilateral lesions and five of the nine bilateral lesions healed and none of the eight “pseudo-bilateral” lesions had healed at the time of final follow-up.

Twenty-three (82%) had an excellent outcome, three (11%) had a good outcome, and two (7%) had a fair result. The rate of return to sports activity did not differ among the three groups.

The authors concluded that an unhealed defect does not preclude a good clinical result or a return to athletic pursuits.

If a non operative treatment don’t obtain any improvement surgical intervention can be considered[9].

Neurological deficit related to spondylolysthesis, a grade 3 or higher grade slip at the presentation are indications for early surgical intervention. Actually more common operative techniques include decompressive laminectomy and several methods of fusion.

Cause the rarity of sacral stress fracture I found only a study who analyzed specifically this disease(17) and a review(9) about back pain who handled this topic.

Shah et al.(17) saw that the best treatment for stress fracture of the sacrum is rest. They showed that most patients are able to return to their normal activity levels in 4 to 6 weeks; the mean time to return to playing a sport is 11/2 months. Athletes are able to gradually return to their sport based on their tolerance.

Conditioning exercises are helpful to treat this disorder and they can be performed in a pool or under the supervision of a physical therapist. To improve comfort of the patients it is possible to use anti-inflammatory agents and analgesics.

Bono(9) state that treatment is always nonoperative, consisting of rest bed and protected or non-weight-bearing. Rest is followed by progressive mobilization weight bearing and activity as symptoms permit. The overall prognosis is favourable but the athletes should be adequately rehabilitated before returning to full activity. Most patients, however, report persistent mild or intermittent pain.

CONCLUSIONS

Acute or chronic back pain can derive from muscular, disk or bony diseases.
An excessive amount of lumbar flexion can lead to back pain, especially if repeated cyclically and with the presence of load.
This is not true for muscular weakness.
To analyse disk disease it is important distinguish among different sports; golf players, football players, cricketers, gymnasts and divers have a higher risk to manifest low-back pain.
Today the link between disk degeneration and back pain is still unclear.
There are discordant opinions about the correlation between bony changes and low-back pain, while there are evidences on the use of SPECT and scintigraphy in order to obtain an early diagnosis of spondylolysis, spodylolisthesis, stress fractures etc.

Author, title and year	Kind of study and aim	Conclusion
15. McGregor AH, Anderton L, Gedroyc WM. The trunk muscles of elite oarsmen. Br J Sports Med. 2002 Jun;36(3):214-7.	Clinical trial. To investigate the trunk strength of elite rowers and the impact of LBP to determinate if asymmetries or weakness were present.	This study suggest that LBP in rowers don't arise as a result of muscle weakness.
11. Caldwell JS, McNair PJ, Williams M. The effects of repetitive motion on lumbar flexion and erector spinae muscle activity in rowers. Clin Biomech (Bristol, Avon). 2003 Oct;18(8):704-11.	Clinical trial. To investigate changes in lumbar flexion together the pattern and level of muscle activity of selected erector spinae during a rowing trial.	Rowers attain relatively high levels of lumbar flexion during the rowing stroke, and these levels are increased during the course of the rowing trial.
10. Bono CM. Low-back pain in athletes. J Bone Joint Surg Am. 2004 Feb;86-A(2):382-96.	Review.	
25. Garces GL, Gonzalez-Montoro I, Rasines JL, Santonja F. Early diagnosis of stress fracture of the lumbar spine in athletes. Int Orthop. 1999;23(4):213-5.	Clinical trial. To confirm the value of planar scintigraphy and SPECT in early diagnosis of lumbar stress fractures.	In a patient with persistent LBP and radiographs a SPECT or a planar scintigraphy may provide the stress fracture diagnosis in some patiesnts.
14. Elliott B, Khangure M. Disk degeneration and fast bowling in cricket: an intervention study. Med Sci Sports Exerc. 2002 Nov;34(11):1714-8.	Clinical trial. To identify the relationship between the incidence of lumbar disk degeneration and bowling technique after 3 yrs of educational intervention.	An educational process aimed at reducing mechanical features that have been linked to back injury decreased the incidence and/or progression of lumbar spine disk degeneration.

30. Young JL, Press JM, Herring SA. The disc at risk in athletes: perspectives on operative and nonoperative care. Med Sci Sports Exerc. 1997 Jul;29(7 Suppl):S222-32.	Review.	
18. Shah MK, Stewart GW. Sacral stress fractures: an unusual cause of low back pain in an athlete. Spine. 2002 Feb 15;27(4):E104-8.	Review – case report. To document the occurrence of sacral stress fracture in athletes and to recommend it in the differential diagnosis of LBP, especially in runners and volleyball players.	Sacral stress fractures are an uncommon cause of LBP in the athlete. Accurate diagnosis is important for the resolution of this disorder.
20. Ogon M, Riedl-Huter C, Sterzinger W, Krismer M, Spratt KF, Wimmer C. Radiologic abnormalities and low back pain in elite skiers. Clin Orthop Relat Res. 2001 Sep;(390):151-62.	Clinical trial. To determine the clinical significance of radiologic abnormalities in screening adolescent who had no symptoms for later development of LBP under high performance training.	Lumbar radiographs are of limited value for predicting LBP. However, end plate lesions properly classified as severe and located anteriorly were significantly related to later development of LBP in athletes doing high performance training.

Table 8: Articles about epidemiological data of low-back pain.

EVIDENCE BASED REHABILITATIVE PROGRAMS FOR LOW-BACK PAIN IN ATHLETES

The results of this search showed that there is evidence that bed rest has no or damaging effects on back pain and there is not difference between a high intensity and a low intensity lumbar extensor training.

Furthermore there is evidence that bench rest after warm-up exercises can have a detrimental effect on lumbar flexibility.

Several data indicates that, with proper training, lumbar flexibility in competitive athletes reaches a plateau that should be maintained by regular stretching, but attempts to push beyond that point in an effort to enhance performance might be detrimental.

The treatment of the disk can be divided in nonoperative and operative intervention; in the first case there are a lot of rehabilitative protocols and all of them states that the therapist has to change exercises depending patient's symptoms.

Also it is recommended that aerobic exercises be incorporated in the rehabilitative program as early as possible.

Operative treatment provides for interbody fusions since the high rate of healing and positive outcomes.

The data used in this study underlined the importance of rest and bracing in treating spondylolysis since their use allowed the return at sport in a great number of athletes and further studies are needed to establish what the exact role of external electrical stimulation should be in the management of patients with spondylolysis.

The rehabilitative projects of sacral stress fractures is always nonoperative and based on rest, but conditioning exercises can be performed in a pool under the supervision of a physical therapist.

Author, title and year	Kind of study and aim	Conclusion
4. Hagen KB, Hilde G, Jamtvedt G, Winnem M. Bed rest for acute low-back pain and sciatica. Cochrane Database Syst Rev. 2004 Oct 18; (4)	Cochrane review. To asses the effects of advice to rest in bed for patients with acute LBP or sciatica.	For people with acute LBP advice to rest in bed is less effective then advice to stay active. For patients with sciatica there's little or not difference between both advices. There's little or no difference in the effect of bed rest compared to exercise, or physiotherapy or 7 days of bed rest compared with 2 or3.
30. Young JL, Press JM, Herring SA. The disc at risk in athletes: perspectives on operative and nonoperative care. Med Sci Sports Exerc. 1997 Jul;29(7 Suppl):S222-32.	Review.	There is no proven benefit of prolonged bed rest. Aerobic fitness may be mildly protective against low-back injury and low-back pain.
18. Shah MK, Stewart GW. Sacral stress fractures: an unusual cause of low back pain in an athlete. Spine. 2002 Feb 15;27(4):E104-8.	Review – case report. To document the occurrence of sacral stress fracture in athletes and to recommend it in the differential diagnosis of LBP, especially in runners and volleyball players.	Sacral stress fractures are an uncommon cause of LBP in the athlete. Accurate diagnosis is important for the resolution of this disorder.
18. Shah MK, Stewart GW. Sacral stress fractures: an unusual cause of low back pain in an athlete. Spine. 2002 Feb 15;27(4):E104-8.	Review – case report. To document the occurrence of sacral stress fracture in athletes and to recommend it in the differential diagnosis of LBP, especially in runners and volleyball players.	Sacral stress fractures are an uncommon cause of LBP in the athlete. Accurate diagnosis is important for the resolution of this disorder.
15. McGregor AH, Anderton L, Gedroyc WM. The trunk muscles of elite oarsmen. Br J Sports Med. 2002 Jun;36(3):214-7.	Clinical trial. To investigate the trunk strength of elite rowers and the impact of LBP to determinate if asymmetries or weakness were present.	This study suggest that LBP in rowers don't arise as a result of muscle weakness.
8. Stasinopoulos D. Treatment of spondylolysis with external electrical stimulation in young athletes: a critical literature review. Br J Sports Med. 2004 Jun;38(3):352-4.	Review. To establish whether external electrical stimulation can decrease pain and heal the defect of the pars interarticularis.	Authors can't conclude whether external electrical stimulation is more effective than other conservative interventions or whether it can be used for the treatment of pars defect.
10. Bono CM. Low-back pain in athletes. J Bone Joint Surg Am. 2004 Feb;86-A(2):382-96.	Review.	

25. Garces GL, Gonzalez-Montoro I, Rasines JL, Santonja F. Early diagnosis of stress fracture of the lumbar spine in athletes. Int Orthop. 1999;23(4):213-5.	Clinical trial. To confirm the value of planar scintigraphy and SPECT in early diagnosis of lumbar stress fractures.	In a patient with persistent LBP and radiographs a SPECT or a planar scintigraphy may provide the stress fracture diagnosis in some patiesnts.
20. Ogon M, Riedl-Huter C, Sterzinger W, Krismer M, Spratt KF, Wimmer C. Radiologic abnormalities and low back pain in elite skiers. Clin Orthop Relat Res. 2001 Sep;(390):151-62.	Clinical trial. To determine the clinical significance of radiologic abnormalities in screening adolescent who had no symptoms for later development of LBP under high performance training.	Lumbar radiographs are of limited value for predicting LBP. However, end plate lesions properly classified as severe and located anteriorly were significantly related to later development of LBP in athletes doing high performance training.
9. Helmhout PH, Harts CC, Staal JB, Candel MJ, de Bie RA. Comparison of a high-intensity and a low-intensity lumbar extensor training program as minimal intervention treatment in low back pain: a randomized trial. Eur Spine J. 2004 Oct;13(6):537-47. Epub 2004 Apr 17.	RCT. The main objective was to perform a RCT on the relative efficacy of a high-intensity, progressive resistance training program of the isolated lumbar extensors.	High-intensity training of the isolated back extensor was not superior to a non-progressive, low-intensity variant in restoring back function in non-specific low back pain.
14. Elliott B, Khangure M. Disk degeneration and fast bowling in cricket: an intervention study. Med Sci Sports Exerc. 2002 Nov;34(11):1714-8.	Clinical trial. To identify the relationship between the incidence of lumbar disk degeneration and bowling technique after 3 yrs of educational intervention.	An educational process aimed at reducing mechanical features that have been linked to back injury decreased the incidence and/or progression of lumbar spine disk degeneration.
11. Caldwell JS, McNair PJ, Williams M. The effects of repetitive motion on lumbar flexion and erector spinae muscle activity in rowers. Clin Biomech (Bristol, Avon). 2003 Oct;18(8):704-11.	Clinical trial. To investigate changes in lumbar flexion together the pattern and level of muscle activity of selected erector spinae during a rowing trial.	Rowers attain relatively high levels of lumbar flexion during the rowing stroke, and these levels are increased during the course of the rowing trial.

Table 9: Articles about rehabilitation of low-back pain.

BIBLIOGRAPHY

1. Adams M., Dolan P.
   A technique for quantifying the bending moment acting on the lumbar spine in vivo.
   J. Biomech. 1991; 24,117-126.
2. Adams M., Hutton W., Stott J.
   The resistance of flexion of the lumbar intervertebral joint.
   Spine 5, 1980; 245-253.
3. Babayev M, Lachmann E, Nagler W.
   The controversy surrounding sacral insufficiency fractures: to ambulate or not to ambulate?
   Am J Phys Med Rehabil. 2000 Jul-Aug;79(4):404-9.
4. Barr KP, Griggs M, Cadby T.
   Lumbar stabilization: core concepts and current literature, Part 1.
   Am J Phys Med Rehabil. 2005 Jun;84(6):473-80.
5. Bartolozzi C., Caramella D., Zampa V., Dal Pozzo G., Tinacci E., Balducci F.
   The incidence of disk changes in volleyball players. The magnetic resonance findings.
   Radiol Med. 1991; 82: 757-60.
6. Bendix AE, Bendix T, Haestrup C, Busch E.
   A prospective, randomized 5-year follow-up study of functional restoration in chronic low back pain patients.
   Eur Spine J. 1998;7(2):111-9.
7. Blanda J., Bethem D.,Moats W.
   Defect of pars interarticularis in athletes : a protocol for nonoperative treatment.
   J Spinal Disord. 1993; 6: 406-11.
8. Bono CM.
   Low-back pain in athletes.
   J Bone Joint Surg Am. 2004 Feb;86-A(2):382-96.
9. Burnett A., Khangure M., Elliot B., Foster D., Hardcastle P.
   Thoracolumbar disk degeneration in young fast bowlers in cricket: a follow-up study.
   Clinic. Biomech. 1996; 11:305-310.
10. Caldwell JS, McNair PJ, Williams M.
    The effects of repetitive motion on lumbar flexion and erector spinae muscle activity in rowers.
    Clin Biomech (Bristol, Avon). 2003 Oct;18(8):704-11.
11. Callaghan JP, Patla AE, McGill SM.
    Low back three-dimensional joint forces, kinematics, and kinetics during walking.
    Clin Biomech (Bristol, Avon). 1999 Mar;14(3):203-16.
12. Cappozzo A., Felici F., Figura F., Gazzani F.
    Lumbar spine loads during half-squat exercises.
    Med Sci Sports Exerc. 1985; 17: 613-620.
13. Cooke PM., Lutz GE.
    Internal disc disruption and axial back pain in the athlete.
    Phys Med Rehabil Clin N Am. 2000; 11: 837-65.
14. d'Hemecourt PA., Zurakowski D., Kriemler S., Micheli LJ.
    Spondylolysis: returning the athlete to sports participation with brace treatment.
    Orthopedics. 2002; 25: 653-7.
15. Daniel J., Polly D., Van Dam B.
    A study of the efficacy of nonoperative treatment of presumed traumatic spondylolysis in a young patient population.
    Mil Med.1995; 160: 553-5.

16. Elliot B., Hardcastle P., Burnett A., Foster D.
The influence of fast bowling and physical factors on radiologic features in high performance young fast bowlers.
Sport. Med. Training Rehabil. 1992; 3:113-130.

17. Elliott B, Khangure M.
Disk degeneration and fast bowling in cricket: an intervention study.
Med Sci Sports Exerc. 2002 Nov;34(11):1714-8.

18. Fellander Tsai L., Micheli L.
Treatment of spondylolysis with external electrical stimulation: a report of two cases.
Clin J Sports Med. 1998; 8: 232-4.

19. Folman Y, Wosk J, Shabat S, Gepstein R.
Attenuation of spinal transients at heel strike using viscoelastic heel insoles: an in vivo study.
Prev Med. 2004 Aug;39(2):351-4.

20. Frost H, Klaber Moffett JA, Moser JS, Fairbank JC.
Randomised controlled trial for evaluation of fitness programme for patients with chronic low back pain.
BMJ. 1995 Jan 21;310(6973):151-4.

21. Frymoyer JW., Newberg A., Pope MH., et al.
Spine radiographs in patients with low-back pain: An epidemiological study in men.
J Bone Joint Surg. 1984; 66A: 1048-1055.

22. Garces GL, Gonzalez-Montoro I, Rasines JL, Santonja F.
Early diagnosis of stress fracture of the lumbar spine in athletes.
Int Orthop. 1999;23(4):213-5.

23. Gatt CJ, Hosea TM, Palumbo RC, Zawadsky JP.
Impact loading of the lumbar spine during football blocking.
Am J Sport Med. 1997; 25: 317-21.

24. Gibson ES.
Incidence of low-back pain and pre-placement x-ray screening.
J Occup Med. 1980; 22:515-519.

25. Green JP., Grenier SG., McGill SM.
Low-back stiffness is altered with warm-up and bench rest: implications for athletes.
Med Sci Sports Exerc. 2002; 34: 1076-81.

26. Greene TL., Hensinger RN., Hunter LY.
Back pain and vertebral changes simulating Scheueman’s disease.
J Pediatr Orthop. 1985; 5:1-7.

27. Gurney B.
Leg length discrepancy.
Gait Posture. 2002 Apr;15(2):195-206.

28. Hagen KB, Hilde G, Jamtvedt G, Winnem M.
Bed rest for acute low-back pain and sciatica.
Cochrane Database Syst Rev. 2004 Oct 18; (4)

29. Harreby M., Neergaard K., Hesselsoe G., et al.
Are radiologic changes in the thoracic and lumbar spine of adolescents risk factors for low-back pain in adults? A 25 years prospective cohort study of 640 schoolchildren.
Spine. 1995; 20: 2298-2302.

30. Helmhout PH, Harts CC, Staal JB, Candel MJ, de Bie RA.
Comparison of a high-intensity and a low-intensity lumbar extensor training program as minimal intervention treatment in low back pain: a randomized trial.
Eur Spine J. 2004 Oct;13(6):537-47. Epub 2004 Apr 17.

31. Hildebrandt VH, Bongers PM, Dul J, van Dijk FJ, Kemper HC.
The relationship between leisure time, physical activities and musculoskeletal symptoms and disability in worker populations.
Int Arch Occup Environ Health. 2000 Nov;73(8):507-18.

32. Hopkins TJ., White AA 3rd.
Rehabilitation of athletes following spine injury.
Clin Sports Med. 1993; 12: 603-19.

33. Jackson DW., Wiltse LL., Dingeman RD., Hayes.
Sress reactions involving the pars interarticularis in young athletes.
Am J Sports Med. 1981; 9: 304-12.

34. Kaufman RL.
Popliteal aneurysm as a cause of leg pain in a geriatric patient.
J Manipulative Physiol Ther. 2004 Jul-Aug;27(6):e9.

35. Kibler WB., Chandler TJ.
Range of motion in junior tennis players participating in an injury risk modification program.
J Sci Med Sport. 2003; 6:51-62.

36. Kirkaldy-Willis WH., Wedge JH., Yong- Hing K., Reilly J.
Pathology and pathogenesis of lumbar spondylosis and stenosis.
Spine. 1978; 3:319-328.

37. Kujala UM, Taimela S., Oksanen A., Salminen JJ.
Lumbar mobility and low back pain during adolescence. A longitudinal three-year follow-up study in athletes and controls.
Am J Sport Med. 1997; 25:363-8.

38. Kujala UM., Oksanen A., Taimela S., Salminen JJ.
Training does not increase maximal lumbar extension in healthy adolescents.
Clinic Biomech. 1997; 12: 181-4.

39. Lamoth CJ, Daffertshofer A, Meijer OG, Lorimer Moseley G, Wuisman PI, Beek PJ.
Effects of experimentally induced pain and fear of pain on trunk coordination and back muscle activity during walking.
Clin Biomech (Bristol, Avon). 2004 Jul;19(6):551-63.

40. Lamoth CJ, Meijer OG, Wuisman PI, van Dieen JH, Levin MF, Beek PJ.
Pelvis-thorax coordination in the transverse plane during walking in persons with nonspecific low back pain.
Spine. 2002 Feb 15;27(4):E92-9.

41. Lang E, Liebig K, Kastner S, Neundorfer B, Heuschmann P.
Multidisciplinary rehabilitation versus usual care for chronic low back pain in the community: effects on quality of life.
Spine J. 2003 Jul-Aug;3(4):270-6.

42. Lundin O., Hellstrom M., Nilsson I., Sward L.
Back pain and radiological changes in the thoraco-lumbar spine of athletes. A long-term follow-up.
Scand J Med Sci Sports. 2001; 11: 103-9.

43. Majkowski GR, Jovag BW, Taylor BT, Taylor MS, Allison SC, Stetts DM, Clayton RL.
The effect of back belt use on isometric lifting force and fatigue of the lumbar paraspinal muscles.
Spine. 1998 Oct 1;23(19):2104-9.

44. Major NM., Helms C.
Sacral stress fractures in long-distance runners.
Am J Roentgenol. 2000; 174: 727-9.

45. Marriott A, Newman NM, Gracovetsky SA, Richards MP, Asselin S.
Improving the evaluation of benign low back pain.
Spine. 1999 May 15;24(10):952-60.

46. McConnell J.
Recalcitrant chronic low back and leg pain--a new theory and different approach to management.
Man Ther. 2002 Nov;7(4):183-92

47. McGill S.
The biomechanics of low back injury: implications on current practice in industry and the clinic.
J. Biomech. 1997; 30 465-475.

48. McGregor AH, Anderton L, Gedroyc WM.
The trunk muscles of elite oarsmen.
Br J Sports Med. 2002 Jun;36(3):214-7.

49. Micheli LI., Wood R.
Back pain in young athletes. Significant differences from adults in causes and patterns.
Arch Pediatr Adolesc Med. 1995; 149: 15-8.

50. Mooney V.
A randomized double blind prospective study of the efficacy of pulsed electromagnetic fields for interbody lumbar fusions.
Spine. 1990; 15: 708-12.

51. O' Sullivan D., Twomey T., Allison G.
Evaluation of specific stabilising exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis or spondylolysthesis.
Spine. 1997; 22: 2959-67.

52. Ogon M, Riedl-Huter C, Sterzinger W, Krismer M, Spratt KF, Wimmer C.
Radiologic abnormalities and low back pain in elite skiers.
Clin Orthop Relat Res. 2001 Sep;(390):151-62.

53. Ong A., Anderson J., Roche J.
A pilot study of the prevalence of lumbar disc degeneration in elite athletes with lower back pain at the Sydney 2000 Olympic Games.
Br J Sports Med. 2003; 37: 263-6.

54. Pettine K., Salib R., Walker S.
External electrical stimulation and bracing for treatment of spondylolysis. A case report.
Spine. 1993; 18: 436-9.

55. Pezzulo D.
Spondylolysis and spondylolisthesis in athletes.
Athletic Therapy Today. 1999; 4: 36-40.

56. Portus M.,
Relationship between cricket fast bowling technique, trunk injuries and ball release speed.
In: XIX International Symposium on Biomechanics in Sports, Blackwell J. (Ed). San Francisco: University of San Francisco Press, 2001; pp. 231-234.

57. Rabago D, Best TM, Beamsley M, Patterson J.
A systematic review of prolotherapy for chronic musculoskeletal pain.
Clin J Sport Med. 2005 Sep;15(5):376-80.

58. Rossi F., Dragoni S.
Lumbar spondylolysis: occurrence in competitive athletes. Update achievements in a series of 390 cases.
J Sport Med Phys Fitness. 1990; 30: 450-2.

59. Sculco AD, Paup DC, Fernhall B, Sculco MJ.
Effects of aerobic exercise on low back pain patients in treatment.
Spine J. 2001 Mar-Apr;1(2):95-101.

60. Shabat S, Gefen T, Nyska M, Folman Y, Gepstein R.
The effect of insoles on the incidence and severity of low back pain among workers whose job involves long-distance walking. Eur Spine J. 2005 Aug;14(6):546-50.

61. Shah MK, Stewart GW.
Sacral stress fractures: an unusual cause of low back pain in an athlete.
Spine. 2002 Feb 15;27(4):E104-8.

62. Soler T., Calderon C.
The prevalence of spondylolysis in the Spanish elite athlete.
Am J Sports Med. 2000; 28: 57-62,.

63. Stasinopoulos D.
Treatment of spondylolysis with external electrical stimulation in young athletes: a critical literature review.
Br J Sports Med. 2004 Jun;38(3):352-4.

64. Steiner ME., Micheli LJ.
Treatment of symptomatic spondylolysis and spondylolisthesis with the modified Boston brace.
Spine. 1985; 10: 937-43.

65. Sugano A, Nomura T.
Influence of water exercise and land stretching on salivary cortisol concentrations and anxiety in chronic low back pain patients.
J Physiol Anthropol Appl Human Sci. 2000 Jul;19(4):175-80.

66. Sward L., Eriksonn B., Peterson L.
Anthropometric characteristics, passive hip flexion, and spinal mobility in relation to back pain in athletes.
Spine 1990; 15:376-382.

67. Sward L., Hellstrom M., Jacobsson B. et al.
Back pain and radiologic changes in the toraco-lumbar spine of athletes.
Spine. 1990; 15: 124-129.

68. Sward L., Hellstrom M., Jacobsson B., Nyman R., Peterson L.
Disc degeneration and associated abnormalities of the spine in elite gymnasts. A magnetic resonance imaging study.
Spine. 1991;16: 437-43.

69. Sys J., Michielsen J., Bracke P., Martens M., Verstreken J.
Nonoperative treatment of active spondylolysis in elite athletes with normal X-ray findings: literature review and results of conservative treatment.
Eur Spine J. 2001; 10: 498-504.

70. Tulder Van M., Malmivaara A., Esmail R., Koes B.
Exercise therapy for low-back pain: a systematic review within the framework of the Cochrane Collaboration Back Review Group.
Spine. 2000; 25: 2784-2796.

71. Van Dien J., Toussant H., Thissen C., van den Ven A.
Spectral analysis of erector spinae EMG during intermittent isometric fatiguing exercise.
Ergonomics 1993; 36 407-414.

72. Videman T., Sarna S., Battie MC., Koskinen S., Gill K., Paananen H., Gibbons L.
The long-term effects of physical loading and exercises lifestyles on back-related symptoms, disability and spinal pathology among men.
Spine. 1995; 20: 699-709.

73. Young JL, Press JM, Herring SA.
The disc at risk in athletes: perspectives on operative and nonoperative care.
Med Sci Sports Exerc. 1997 Jul;29(7 Suppl):S222-32.