

# Search for effective treatment techniques for professional athletes with lower back pain.

ANTON BOTOV<sup>1</sup>, PAVEL SHNYAKIN<sup>1,2</sup>, ALEKSANDER OSIPOV<sup>2,3,4</sup>, TATYANA ZHAVNER<sup>3</sup>

<sup>1</sup>Regional Clinical Hospital, Krasnoyarsk, RUSSIA

<sup>2</sup>Krasnoyarsk State Medical University named after Professor V.F. Voyno-Yasenetsky, Krasnoyarsk, RUSSIA

<sup>3</sup>Siberian Federal University, Krasnoyarsk, RUSSIA

<sup>4</sup>Siberian Law Institute of the Ministry of Internal Affairs of the Russian Federation, Krasnoyarsk, RUSSIA

E-mail: [ale44132272@yandex.ru](mailto:ale44132272@yandex.ru)

**Abstract:** Lower back pain (LBP) is a common complaint of a significant number of the athletes. Both young and elite athletes consult the doctors with complaints about LBP. One of the main causes of LBP is diskal hernia or spondylolysis. The main methods of the treatment of this disease are: spondylosis and surrogation of the lumbar disc. In the medical reports there are positive clinical results using both methods. However, the scientific disputes continue over the comparative evaluation of the effectiveness of the methods of spondylolysis and surrogation of the lumbar disc. The authors analyzed the results of the surgical treatment of the 18 professional athletes. In the period from 2012 to 2013 an operation was performed to these athletes to replace the degenerative intervertebral disk disease at the level of L5-S1. A total resection of the intervertebral disc at the level of the lumbar spine with decompression of the dural sac and the subsequent installation of the functional endoprosthesis - M6-L Artificial Lumbar Disc was performed to the first group of athletes (n = 10). The transforaminal lumbar interbody fusion (TLIF) and transpedicular screws after removing the diskal hernia L5-S1 was performed to the second group of athletes (n = 8). The best clinical result was achieved in the first group of the athletes. Only 8 out of 10 athletes with surrogation of the lumbar disc were able to return to their previous level of sporting achievements for two years after the operation. X-ray results showed the safety of endoprosthesis functions throughout the study period. The six athletes from the second group completed their sports career within 2 years after the spondylolysis. The cause was the increase in degenerative processes at the adjacent spine level and an increase in LBP.

**Key words:** the professional sports; LBP; diskal hernia; spondylolysis; surrogation of the lumbar disc; endoprosthesis replacement of the disc; the return to the sport.

## Introduction

It is generally agreed today that during the life the most people experience lower back pain (LBP). This pain becomes chronic with age and relapse. This is dictated by many different factors which are important for the development of the chronic low back pain: disc hernia, spondylolysis, degenerative disc disease, etc. (Lee, Zotti & Osti, 2016; Sairyo & Nagamachi, 2016). According to the doctors the dominant cause of the development of the pain in the lumbosacral spine is the degeneration of intervertebral discs (Byvaltsev, et al., 2017). This disease leads to disability; it lowers the quality of life and reduces its ability to work. However, these negative consequences have a significant socio-economic burden on the patients and society as a whole which leads to a significant health system costs (Vinnik, et al., 2014; Sitthipornvorakul, et al., 2011). It is known that back pain is quite common not only between the physically inactive population and also the athletes have it too but the mechanisms of their presence have not been sufficiently studied (Fett, Trompeter, & Platen, 2017). Besides, the athletes spend most of their time in training and competition which leads to a rather high level of mechanical stress and stress on the spine of the athletes (Dunn, Proctor, & Day, 2006). The level of stress depends on the duration and intensity of training, sports discipline and the number of competitions during the year (Mortazavi, Zebardast & Mirzashahi, 2015). At the same time there was no apparent dependence of the presence of the lower back pain with the specificity of a particular sport. The lower back pain is quite common among the athletes representing different kinds of sports: martial arts, sports and gymnastics etc. (Osipov, et al., 2017, Osipov, Iermakov, et al., 2017; Bolotin & Bakayev, 2016). The elite athletes have the presence and spread of back pain which has been investigated by many scientists. But in view of the methodological heterogeneity of the studies the rates of the back pain which the athletes have can vary quite significantly including a description of the exact area of the pain, its duration and intensity (Trompeter, Fett, & Platen, 2017).

It is known that the back pain is a fairly common complaint of a large number both young (Patel, & Kinsella, 2017, Malkogeorgos, et al., 2011) and elite athletes (Lariosa, et al., 2017; De Luigi, 2014). It has been established that about 30% of the athletes have complaints about lower back pain throughout the sports career (Cherepanov, & Nazaryan, 2013; Dreisinger, & Nelson, 1996). This symptom is one of the most common reasons for missing trainings among the elite athletes. It was revealed that 75% of elite athletes have complaints

about the back pain (Ong, Anderson, & Roche, 2003). The most common cause of the athletes' complaints about low back pain is degenerative disc disease, disc hernia or spondylolysis (Burgmeier, & Hsu, 2014).

It is generally agreed that there are several methods of conservative treatment of LBP athletes, disc hernia and spondylolysis involving the return of the patients to their active sports activities (Iwamoto, Takeda, & Wakano, 2004). However, the experts argue that there is no agreement on the choice of the optimal strategy for treating lumbar disc herniation of the athletes. Currently, there is a lack of controlled studies of various methods of conservative and surgical treatment of the athletes with a diagnosis of a hernia of the lumbar disc. The experts argue that the limited data on the effectiveness of surgical treatment of spondylolysis in comparison with the conservative treatment do not allow making unequivocal conclusions about the advantages of this or that method (Scheepers, Streak, & Munn, 2015, Parker, et al., 2014). At the same time the doctors do not have sufficient evidence of the effectiveness of the use of drugs in the treatment of spondylolysis and lumbar disc herniation (Jordon, Konstantinou, & O'Dowd, 2009). The most of the literature contains data on the return of the athletes to the sports after a spinal injury. Accurate data on the return to a sports career after surgery on the spine is presented significantly less (Christman, & Li, 2016). We can say about the criteria and limits that indicate the need for conservative or surgical treatment of LBP and herniated athletes are not very clear and the physicians need to evaluate each athlete individually (Wajchemberg, et al., 2002).

The main attention of many doctors is now paid to the search for claim that the replacement of the lumbar disc (TDR) is now a well-studied and tested technology. Noticeable this technology provides better clinical results than disk merging operations or the establishment of protective structures on adjacent disks (Zigler, & Garcia, 2015). The specialists recommend lumbar TDR for the young patients who do not suffer from the significant joint deformities or osteoporosis (Salzmann, et al., 2017). At the same time, there are studies suggesting that no specific clinical differences between disc replacement operations and spinal fusion techniques have been identified at this time. One should note here that the new scientific studies with a long observation period and a sufficient number of studies are needed to evaluate the safety and quality of TDR (Lee, Zotti, & Osti, 2016; van den Eerenbeemt, et al., 2010). For example, many athletes of TDR can be recommended only in the absence of a positive reaction of the athletes to vigorous conservative treatment (Majcen, Pungartnik, & Sarabon, 2014).

The scientists note that despite the increasing popularity of lumbar disc replacement of the athletes there is a lack of research on the potential risks after such an operation (Siepe, Wiechert, Khattab, et al., 2007). Along with various mechanical problems the level of stability of the implant with respect to its bearing capacity is also unknown during the significant loads during the sports activities. Thus, at present, a serious scientific discussion continues on the effectiveness of various treatments for LBP caused by spondylolysis or degenerative lumbar disc disease which the professional athletes have.

Thus the aim of the authors' research was to study the effectiveness of TDR with the installation of the interbody endoprosthesis - M6-L Artificial Lumbar Disc in comparison with the method of spondylodesis of the professional athletes.

## **Material & methods**

It should be taken into account that the investigations were carried out on the basis of the neurosurgical department of the regional clinical hospital (Krasnoyarsk) in the period from 2012 to 2015. The contingent of the researched is 18 professional athletes who underwent surgery for the degenerative disc hernia at the level of L5-S1 during 2012-2013. The age of the researched is from 19 to 32 years. The athletes represented various kinds of sports: powerlifting, hockey, figure skating and combat sports. Besides, all athletes address to the clinic complaining of continuing and increasing pain in the back and legs after a course of complex conservative therapy lasting from 2 to 6 weeks. This therapy included the use of anti-inflammatory drugs, muscle relaxants, physiotherapy, manual therapy and a course of paravertebral blockades. Moreover, during the examination all athletes were diagnosed with dorsopathy with lumbar-ischiadicus and painful radicular syndrome on the background of the disc herniation and a decrease in the height of the L5-S1 disc.

What is more that the athletes were divided into two groups: TDR (n = 10) and Fusion (n = 8). performed a total resection of the intervertebral disc at the level of the lumbar spine with decompression of the dural sac and the subsequent installation of the functional endoprosthesis - M6-L Artificial Lumbar Disc was performed to the first group of the athletes (TDR). The transforaminal lumbar interbody fusion (TLIF) and transpedicular screws after removing the diskal hernia L5-S1 was performed to the second group of the athletes (n = 8) (Fusion).

The assessment of the lower back pain and lower limbs of the patients was carried out using the Visual Analogue Scale (VAS). The assessment of the level of quality of life of the patients was conducted using the Russian Oswestry Disability Index (ODI). According to many experts, the Russian Oswestry Disability Index is a fairly reliable and valid tool for assessing the degree of disability of the patients (Bakhtadze, Bolotov, & Kuzminov, 2016). The following instrumental studies were also performed: magnetic resonance tomography (MRI) of the lumbar spine and lumbar spondylography with the functional tests. The following was estimated:

the height of the affected disc, sagittal translation and angulation of the operated segment. The experts often say that the state of the intervertebral disc and facet joints at the operated and adjacent levels were assessed using the classification of A. Fujiwara (Fujiwara, et al., 2000).

## Results

In the first group of the athletes the pain of the radicular syndrome decreased for the 9 patients a month after the total resection of the intervertebral disc and the installation of the endoprosthesis. A decrease in the lumbar syndrome was also found for the 9 athletes of the first group. A year later, a decrease in these syndromes was found for the 8 athletes of the first group. In two years of observation these indicators have not changed. The assessment of the level of the quality of life (ODI) conducted according to the Russian Oswestry Disability Index revealed a significant improvement of the quality of life of the athletes of the first group during the first week after the operation. On average, the level of quality of life improved from  $41.7 \pm 4.2$  to  $8.1 \pm 1.0$  points according to ODI. A month after the operation the score improved to  $3.3 \pm 1.1$  points for ODI. In the future, for two years, the indicators of assessing the quality of life of the athletes of the first group have not changed significantly.

For two years after the operation the execution of control MRI examinations of the lumbosacral spine showed that 2 athletes from the first group showed an increase in degenerative processes at an adjacent level of the spinal column. In particular, the growth of facet joint degeneration was detected from 2 to 4 points according to the classification of A. Fujiwara (Fujiwara, et al., 2000). The increased physical exertion caused the increase of the pain syndrome of these athletes that did not allow them to return to the active training sessions. Thus, two years after the operation of installing a functional endoprosthesis in the lumbar spine 8 out of 10 athletes were able to return to the continuation of their sports career. The data of MRI examinations of the lumbosacral spine of the first group of athletes before and after surgery are shown on Pictures 1 and 2. Picture 1 shows the characteristic MRI of the athlete before the operation. Herniated disc L5-S1 was detected on the background of a decrease of the disc height by 25%. Picture 2 shows the typical for the most athletes of the first group of MRI after the operation. The hernia of the disk is completely removed and the compression of the dural sac and rootlets is not revealed. There is a good visualization despite the implant installed to the athlete. The control functional radiography of the lumbosacral spine performed at the clinic in 12 months and 24 months after the operation showed that heterotopic ossification of the operated segment of the athletes was not detected. Sagittal translation and angulation in the operated segment was limited by the technical characteristics of the endoprosthesis and was about  $4.80 \pm 1.60$ .



Pic. 1.

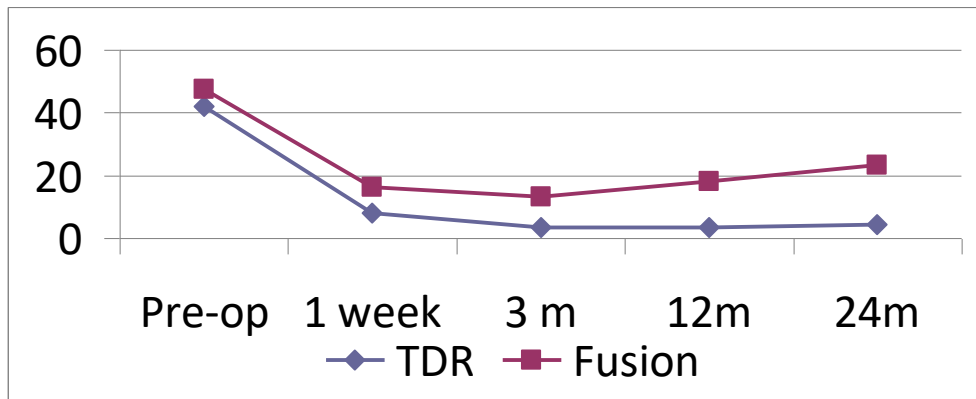


Pic. 2

Perhaps, in the second group of the athletes a month after the implementation of the spondylodesis the pain of the radicular syndrome decreased between 6 people. The reduction of lumbar syndrome was recorded between 5 athletes. Three athletes returned to the active training but they had to stop the training sessions because of the growing pain symptom in the lower back. Thus, a year after the operation the pain syndrome was absent between 6 patients and lumbalgic between 4 athletes. MRI-examination of the lumbosacral spine of the athletes of the second group revealed an increase in degenerative processes at the adjacent spine level of the 6 athletes. These processes were the clinical cause of lumbalgic syndrome. Meanwhile, 2 years after the spondylodesis one athlete needed a re-surgery and the rest of the patients in this group underwent a conservative course of the treatment. By the way the level of quality of life of the athletes of the second group averaged a week after the operation improved from  $47.3 \pm 3.1$  to  $16.3 \pm 1.5$  points according to the Russian Oswestry Disability Index. It should be noted that a month later, the assessment (ODI) against the background of the

therapy was between  $13.1 \pm 2.0$  points. A year after the spondylodesis the level of quality of life activity averaged between  $18 \pm 3,8$  points and in 2 years was  $23,3 \pm 4,1$  points.

Nevertheless, the changes in data on the assessments of the level of quality of life of the first group of athletes (TDR) and the athletes of the second group (Fusion) after surgical treatment are presented in Picture 3.



Pic. 3

## Discussion

It is a well-known fact that the physicians believe that back pain is a common problem for the professional athletes. The most common cause of the lower back pain (LBP) is spondylosis (Daniels, et al., 2011). Spondylosis is the cause of the appearance of radicular syndrome or radiculopathy complicated by the presence of a hernia of the lumbar disc. Besides, the scientific literature supports both conservative treatment and surgical intervention in the treatment of radiculopathy caused by a hernia of the lumbar disc (Schoenfeld, & Weiner, 2010). At the same time it is noted that only very few methods of the treatment are really efficient (Petering, & Webb, 2011). Moreover, the clinical studies show that many athletes after the course of treatment can not return to the previous level of the sports activity (Puentedura, & Louw, 2012). In particular it was revealed that conservative methods of treating athletes with symptomatic hernia of the lumbar disc have only a short-term result (Iwamoto, Sato, Takeda, et al., 2011). The experts say that long conservative treatment should be avoided which can have a negative impact on the success of surgical treatment of the patients. Meanwhile, the relative indicators for surgical treatment can be: increased pain in the back and legs and the inability of the competitive activity among the athletes (Dunn, Proctor, & Day, 2006). The low back pain adversely affects the flexibility and strength of the athletes which prevents them from returning to their previous sporting level (Ashmen, Swanik, & Lephart, 1996).

Furthermore, in the medical literature there is evidence that the surgical treatment of motor weakness caused by a hernia of the lumbar disc facilitates the rapid restoration of motor functions (Choi, et al., 2013). Thus, for the professional athletes whose conservative treatment has not been successful the surgical treatment remains the only chance of reducing back pain and returning to the active sports (Scheepers, Streak, & Munn, 2015). What is more there is evidence that surgical treatment of lumbar spine states gives the excellent results to the athletes. The replacement of a herniated lumbar disc allows the athletes to continue their careers at the preoperative levels of achievement (Cook, & Hsu, 2016). At the same time, there are studies that indicate the difficulty of returning to an active sports career after the treatment of spondylolysis (Li, & Hresko, 2012).

It should be noted that the importance of rehabilitation after the end of surgical or conservative treatment of LBP. From the one hand the doctors say that many rehabilitation prescriptions can not cope with the violations of postural and motor control which are the characteristic for the sports activities which can impede the athletes' full-fledged sports activity after the treatment (VanGelder, Hoogenboom, & Vaughn, 2013). From the other hand some experts recommend the hydrotherapy to the athletes who undergo surgery to remove a disc herniation as rehabilitation. However, there is a scientific discussion regarding to the search of the most effective form of rehabilitation for the athletes after the surgical treatment. In particular, there are different opinions in determining the time at which rehabilitation activities begin (Wajchemberg, et al., 2002).

It should be mentioned that the experts argue that with a constant increase in training loads during the sports there are significant concerns about the stability of the implant and new fairly lengthy studies with a large number of patients are needed (Siepe, Wiechert, Khattab, et al., 2007). However, carrying out such studies is associated with some difficulties. So it should be noted that the development of prosthetics of the lumbar disc between the athletes is hampered by the relatively high cost of such operations. On average, in the Russian Federation, the operation to replace the disc is estimated at \$ 6-7 thousand and the spondylodesis is estimated about \$ 2-3 thousand. Thus, the most athletes choose spondylodesis only because of a lack of financial resources and not because of the high efficiency of such an operation. Thus, there are objective difficulties with qualitative observation of a sufficient number of patients with TDR.

## Conclusions

Perhaps we should also point out the fact that the studies show that resection of the intervertebral disc at the lumbar level with the implantation of a functional endoprosthesis is a fairly safe and productive method of treating the professional athletes with problems with herniated discs and the presence of radiculopathy. Moreover, a positive clinical result in the form of regression of painful radicular and lumbar syndrome and the possibility of continuing a sports career was achieved between 8 out of 10 first-group athletes (TDR) after removing their disc herniation with subsequent prosthetics. Furthermore, X-ray results of the authors' studies showed the safety of the endoprosthesis functions throughout the research period. The preservation of the functions of the endoprosthesis allows avoiding the growth of degenerative processes at the adjacent level of the spinal column and the appearance of the pain syndromes. The authors hope that these studies will make a necessary contribution to solving the problem of finding effective treatment for the athletes with LBP and hernia lumbar disc.

**Conflicts of interest** - If the authors have any conflicts of interest to declare.

## References.

- Ashmen, K., Swanik, C., & Lephart, S. (1996). Strength and flexibility characteristics of athletes with chronic low-back pain. *Journal of Sport Rehabilitation*, 5(4). 275-286. <https://doi.org/10.1123/jsr.5.4.275>
- Bakhtadze, M., Bolotov, D., & Kuzminov, K. (2016). Oswestry disability index: A study of reliability and validity of the Russian version. *The Manual Therapy Journal*, 4(64). 24-33. [In Russian]
- Bolotin, A., & Bakayev, V. (2016). Efficacy of using isometric exercises to prevent basketball injuries. *Journal of Physical Education and Sport*, 4. 1177-1185. DOI:10.7752/jpes.2016.04188
- Burgmeier, R., & Hsu, W. (2014). Spine surgery in athletes with low back pain-considerations for management and treatment. *Asian Journal of Sports Medicine*, 5(4). e24284. DOI:10.5812/asjasm.24284
- Byvaltsev, V., et al., (2017). Analysis of results of the intervertebral total disk arthroplasty of the lumbar spine by M6-L prosthesis: a multicenter study. *Annals of the Russian Academy of Medical Sciences*, 5(72). 393-402. DOI:10.15690/vramn782
- Cherepanov, E., & Nazaryan, S. (2013). Low back pain in elite athletes. *Exercise Therapy and Sports Medicine*, 8(116). 42-48. [In Russian]
- Choi, H., et al. (2013). Surgical versus conservative treatment for lumbar disc herniation with motor weakness. *Journal of Korean Neurosurgical Society*, 54(3). 183-188. DOI:10.3340/jkns.2013.54.3.183
- Christman, T., & Li, Y. (2016). Pediatric return to sports after spinal surgery. *Sports Health*, 8(4). 331-335. <https://doi.org/10.1177/1941738116634685>
- Cook, R., & Hsu, W. (2016). Return to play after lumbar spine surgery. *Clinics in Sports Medicine*, 35(4). 609-619. DOI:10.1016/j.csm.2016.05.006
- Daniels, J., et al. (2011). Evaluation of low back pain in athletes. *Sports Health*, 3(4). 336-345. DOI:10.1177/1941738111410861
- De Luigi, A. (2014). Low back pain in the adolescent athlete. *Physical Medicine and Rehabilitation Clinics of North America*, 25(4). 763-788. <https://doi.org/10.1016/j.pmr.2014.06.004>
- Dreisinger, T., & Nelson, B. (1996). Management of back pain in athletes. *Sports Medicine*, 21(4). 313-320.
- Dunn, I., Proctor, M., & Day, A. (2006). Lumbar spine injuries in athletes. *Neurosurgical Focus*, 21(4). 1-5. DOI:10.3171/foc.2006.21.4.5
- Fett, D., Trompeter, K., & Platen, P. (2017). Back pain in elite sports: A cross-sectional study on 1114 athletes. *PLoS ONE*, 12(6). e0180130. <https://doi.org/10.1371/journal.pone.0180130>
- Fujiwara, A., et al. (2000). The relationship between disc degeneration, facet joint osteoarthritis, and stability of the degenerative lumbar spine. *Journal of Spinal Disorders*, 13(5). 444-450.
- Iwamoto, J., Sato, Y., Takeda, T., et al. (2011). Return to play after conservative treatment in athletes with symptomatic lumbar disc herniation: a practice-based observational study. *Open Access Journal of Sports Medicine*, 2. 25-31. DOI:10.2147/OAJSM.S17523
- Iwamoto, J., Takeda, T., & Wakano, K. (2004). Returning athletes with severe low back pain and spondylolysis to original sporting activities with conservative treatment. *Scandinavian Journal of Medicine & Science in Sports*, 14(6). 346-351.
- Jordon, J., Konstantinou, K., & O'Dowd, J. (2009). Herniated lumbar disc. *BMJ Clinical Evidence*, 2009: 1118. PMC2907819
- Lariosa, C., et al. (2017). Survey of judo injuries in physical education classes: a retrospective analysis. *Journal of Physical Education and Sport*, 3. 2034-2042. DOI:10.7752/jpes.2017.03205
- Lee, Yu., Zotti, M., & Osti, O. (2016). Operative management of lumbar degenerative disc disease. *Asian Spine Journal*, 10(4). 801-819. DOI:10.4184/asj.2016.10.4.801

- Li, Y., & Hresko, M. (2012). Lumbar spine surgery in athletes: outcomes and return-to-play criteria. *Clinics in Sports Medicine*, 31(3). 487-498. DOI:10.1016/j.csm.2012.03.006
- Majcen, Z., Pungartnik, T., & Sarabon, N. (2014). Consideration for lumbar disc degeneration and herniation in sports. *Internet Journal of Allied Health Sciences and Practice*, 12(2). Article 6. <http://nsuworks.nova.edu/ijahsp/vol12/iss2/6/>
- Malkogeorgos, A., et al. (2011). Common dance related musculoskeletal injuries. *Journal of Physical Education and Sport*, 3. 259-266.
- Mortazavi, J., Zebardast, J., & Mirzashahi, B. (2015). Low back pain in athletes. *Asian Journal of Sports Medicine*, 6(2). e24718. DOI:10.5812/asjms.6(2)2015.24718
- Ong, A., Anderson, J., & Roche, J. (2003). A pilot study of the prevalence of lumbar disc degeneration in elite athletes with lower back pain at the Sydney 2000 Olympic Games. *British Journal of Sports Medicine*, 37(3). 263-266. DOI:10.1136/bjms.37.3.263
- Osipov, A., Kudryavtsev, M., Fedorova, P., et al. (2017). Comparative analysis of the scientific views of Russian and foreign scientists on the problem of training skilled judo wrestlers. *Journal of Physical Education and Sport*, 1. 288-293. DOI:10.7752/jpes.2017.01043
- Osipov, A., Kudryavtsev, M., Iermakov, S., et al. (2017). Topics of doctoral and postdoctoral dissertations devoted to judo in period 2000-2016 – the overall analysis of works of Russian experts. *Archives of Budo*, 13. 1-10.
- Parker, S., et al. (2014). Two-year comprehensive medical management of degenerative lumbar spine disease (lumbar spondylolisthesis, stenosis, or disc herniation): a value analysis of cost, pain, disability, and quality of life: clinical article. *Journal of Neurosurgery. Spine*, 21(2). 143-149. DOI:10.3171/2014.3.SPINE1320
- Patel, D., & Kinsella, E. (2017). Evaluation and management of lower back pain in young athletes. *Translational Pediatrics*, 6(3). 225-235. DOI:10.21037/tp.2017.06.01
- Petering, R., & Webb, C. (2011). Treatment options for low back pain in athletes. *Sports Health*, 3(6). 550-555. DOI:10.1177/1941738111416446
- Puentedura, E., & Louw, A. (2012). A neuroscience approach to managing athletes with low back pain. *Physical Therapy in Sport*, 13. 123-133.
- Sairyo, K., & Nagamachi, A. (2016). State-of-the-art management of low back pain in athletes: Instructional lecture. *Journal of Orthopaedic Science*, 21(3). 263-272. <https://doi.org/10.1016/j.jos.2015.12.021>
- Salzmann, S., et al. (2017). Lumbar disc replacement surgery—successes and obstacles to widespread adoption. *Current Reviews in Musculoskeletal Medicine*, 10(2). 153-159. DOI:10.1007/s12178-017-9397-4
- Scheepers, M., Streak, J., & Munn, Z. (2015). The effectiveness of surgical versus conservative treatment for symptomatic unilateral spondylolysis of the lumbar spine in athletes: a systematic review. *JBIS Database of Systematic Reviews Implementation Reports*, 13(3). 137-173. DOI:10.11124/jbisrir-2015-1926
- Schoenfeld, A., & Weiner, B. (2010). Treatment of lumbar disc herniation: Evidence-based practice. *International Journal of General Medicine*, 3. 209-214.
- Siepe, C., Wiechert, K., Khattab, M., et al. (2007). Total lumbar disc replacement in athletes: clinical results, return to sport and athletic performance. *European Spine Journal*, 16(7). 1001-1013. DOI:10.1007/s00586-006-0257-y
- Sitthipornvorakul, E., et al. (2011). The association between physical activity and neck and low back pain: a systematic review. *European Spine Journal*, 20(5). 677-689. <https://doi.org/10.1007/s00586-010-1630-4>
- Trompeter, K., Fett, D., & Platen, P. (2017). Prevalence of back pain in sports: A systematic review in literature. *Sports Medicine*, 47(6). 1183-1207. <https://doi.org/10.1007/s40279-016-0645-3>
- Wajchemberg, M., et al. (2002). Early rehabilitation of athletes using hydrotherapy after surgical treatment of lumbar disc herniation: preliminary report of three cases. *Acta Ortopedica Brasileira*, 10(2). 48-57. <http://dx.doi.org/10.1590/S1413-78522002000200007>
- van den Eerenbeemt, K., et al. (2010). Total disc replacement surgery for symptomatic degenerative lumbar disc disease: a systematic review of the literature. *European Spine Journal*, 19(8). 1262-1280. DOI:10.1007/s00586-010-1445-3
- VanGelder, L., Hoogenboom, B., & Vaughn, D. (2013). A phased rehabilitation protocol for athletes with lumbar intervertebral disc herniation. *International Journal of Sports Physical Therapy*, 8(4). 482-516.
- Vinnik, Yu., et al. (2014). Contemporary view on the problem of treatment the patients with postoperative ventral hernias. *Siberian Medical Review*, 6(90). 5-13. [In Russian]
- Zigler, J., & Garcia, R. (2015). ISASS policy statement – lumbar artificial disc. *International Journal of Spine Surgery*, 9. 7. DOI:10.14444/2007