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MUSCULOSKELETAL CONDITION AND ADAPTATION AS THE PREDICTORS OF LOW BACK PAIN IN SPORTS GAMES

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Abstracts

Objective. The objective of this systematic review of literature was to identify if the musculoskeletal condition and disorders caused by adaptation on specific movement patterns in sports games is as risk factors of low back pain (LBP). ***Data sources.*** A comprehensive search of articles published in the last 20 years was conducted in four databases (PubMed®, Google Scholar, Web of Science). Different combinations of keywords such as LBP, muscle imbalance, muscle strength, muscle endurance, musculoskeletal system and sport game were used, applying the Boolean operators. After establishing the criteria of selection, 9 studies of 52 initially identified were analyzed. ***Results.*** From the viewpoint of musculoskeletal condition and its functional adaptation as the possible risk factors of LBP in the sports games it is suggested that the musculoskeletal system, its functional disorders, endurance and maximal strength of the trunk muscles are not risk factors of LBP in every aspect. The risk factors appear to be muscle imbalances combined with functional asymmetry of pelvic and its asymmetrical rotation as a result of unilateral overloading, as well as the low maximal lumbar[flexion. Low level of endurance of trunk and core muscles cannot be uniquely identified as a risk factor of LBP. Similarly, the maximal isometric strength of trunk muscles do not act as a risk factor of LBP, either. ***Conclusion.*** A detailed comparison of data between the sports games, within game, sex or age was not possible. Further research is necessary. Nevertheless, based on the results of this review, it is obvious that in sports games LBP is a consequence of functional and structural changes of pelvic and related muscles. There is less evidence for endurance and maximal isometric strength of trunk muscles to be a risk factor of LBP.

Key words: low back pain, musculoskeletal condition, adaptation, sports games.

Людмила Заплеталова, Габріела Луптакова. Умови адаптації опорно-рухового апарату як предикаторів виникнення болю в попереково-крижовому відділі в спортивних іграх. ***Мета дослідження*** – з’ясувати, чи розлади опорно-рухового апарату, спричинені адаптацією до конкретних рухових вправ у спортивних іграх, є факторами ризику виникнення болю в попереку (LBP). ***Джерела збору даних.*** Опрацьовано наукові статті, опубліковані за останні 20 років у чотирьох базах даних (PubMed®, Google Scholar, Web of Science). Застосовано різні комбінації ключових слів, такі як LBP, дисбаланс м’язів, сила м’язів, витривалість м’язів, опорно-руховий апарат і спортивна гра. Після визначення критеріїв відбору проаналізовано дев’ять із 52 наявних досліджень. ***Результати дослідження.*** Із погляду стану опорно-рухового апарату та його функціональної адаптації як можливих факторів виникнення ризику LBR у спортивних іграх можемо вважати, що опорно-руховий апарат, його функціональні порушення, витривалість і максимальна сила м’язів тулуба не є чинниками ризику виникнення LBR. Натомість виявлено такі фактори ризику, як дисбаланс м’язів у поєднанні з функціональною асиметрією таза та його асиметричним обертанням у результаті одностороннього перевантаження, а також максимально сильним згинанням у попереку. Низький рівень витривалості м’язів тулуба й основних м’язів однозначно не є визначальним фактором ризику LBR. Аналогічно, що максимальна ізометрична сила м’язів тулуба не виступає фактором ризику LBR. ***Висновки***. Не вдалося детально зібрати дані про фізичний стан між спортивною грою, а також під час гри, зокрема порівняти їх за статтю чи віком. ***Перспективи дослідження.*** Отже, виходячи з результатів нашого дослідження, бачимо, що очевидним є той факт, що в спортивних іграх LBR є наслідком функціональних і структурних змін тазових та супутніх м’язів. Менш доказовим залишається той факт, що витривалість і максимальна ізометрична сила м’язів тулуба є фактором ризику LBR.

Ключові слова: біль у попереково-крижовому відділі, стан опорно-рухового апарату, адаптація, спортивні ігри.

Людмила Заплеталова, Габриэла Луптакова. Условия адаптации опорно-двигательного аппарата как предикторов возникновения боли в пояснично-крестцовом отделе в спортивных играх. ***Цель исследования*** – выяснить, являются ли факторами риска возникновения боли в пояснице (LBP) расстройства опорно-двигательного аппарата, вызванные адаптацией к конкретным двигательным упражнениям в спортивных играх. ***Источники сбора даннях.*** Обработано научные статьи, опубликованные за последние

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20 лет в четырех базах данных (PubMed®, Google Scholar, Web of Science). Применялись различные комбинации ключевых слов, такие как LBP, дисбаланс мышц, сила мышц, выносливость мышц, опорно-двигательный аппарат и спортивная игра. После определения критериев отбора анализировались девять с 52 имеющихся исследований. ***Результаты исследования.*** С точки зрения состояния опорно-двигательного аппарата и его функциональной адаптации как возможных факторов возникновения риска LBR в спортивных играх можем считать, что опорно-двигательный аппарат, его функциональные нарушения, выносливость и максимальная сила мышц туловища не являются факторами риска возникновения LBR. Зато наблюдаются следующие факторы риска, такие как дисбаланс мышц в сочетании с функциональной асимметрией таза и его асимметричным вращением в результате односторонней перегрузки, а также максимально сильным сгибанием в пояснице. Низкий уровень выносливости мышц туловища и основных мышц однозначно не является определяющим фактором риска LBR. Аналогично максимальная изометрическая сила мышц туловища не выступает фактором риска LBR. ***Выводы.*** Не удалось детально собрать данные о физическом состоянии между спортивной игрой, а также во время игры, в частности сравнить их по полу или возрасту. ***Перспективы исследования.*** Таким образом, исходя из результатов нашего исследования, очевидным является тот факт, что в спортивных играх LBR является следствием функциональных и структурных изменений тазовых и сопутствующих мышц. Менее доказательным остается тот факт, что выносливость и максимальная изометрическая сила мышц туловища являются факторами риска LBR.

Ключевые слова: боль в пояснично-крестцовом отделе, состояние опорно-двигательного аппарата, адаптация, спортивные игры.

Introduction. Although sedentary lifestyle is considered to be one of the risk factors of back pain, on the contrary, also an extreme training load with a lack of sufficient regeneration might be the cause. The back pain is a common problem in sports, a low back pain (LBP) especially. The LBP might be caused by the acute injuries as well as the overuse injuries. However, the fact that the long lasting demands of sport training are connected with a higher prevalence of LBP is not unequivocal. The research in this area is ambiguous. Some results confirm the correlation, but the others dispute it [1; 2; 3]. Regarding young athletes, it is well known that the spine abnormalities and LBP occur around 13 years of age. Prevalence of LBP increases throughout the growth spurt. The prevalence of repetitive LBP in adolescents occurs most often between 20 to 30 %, depending on the type of sport. The cause might be also found in cases such as acute and overuse injuries and repetitive unilateral overload of soft and bony tissues, which is very often underestimated [4; 5]. Certain predispositions include musculoskeletal imbalance caused by imbalance between bone and ligaments growth, decreased flexibility, structural changes of spine and load extremes, although this has not always been confirmed [6].

The causes of back pain are mostly multifactorial. Even risk factors in sports games related to back pain, mainly LBP, represent a very wide range. The fundamental division is to internal and external factors (table 1).

Table 1

Fundamental Risk Factors of Back Pain in Sports Games [Modified by 7, 8].

Intrinsic Factors
Anatomy
Spinal dimension
Posture
Trunk weight
Biomechanics
Centre of body mass position
Game skill techniques
Biological
Gender
Age
Individual competitive and game activity of player
Hours of game/training played
Technique utilized
Level, category and role of the player in the game
Extrinsic factors
Type of the sports game
Training and game conditions
Type of shoes

However the range of both internal and external risk factors is much wider. Other familiar internal risk factors include body height which is significantly above-average in a number of sports games, pain occurred in the past, acute injuries of back and lower limbs, muscular imbalance, pelvic asymmetry, spine degeneration and flexibility, untreated microtrauma and back injuries, poor strength, muscular endurance of trunk and core. Among other external factors belong e.g. history of back pain in the family, incorrect technique utilized, etc. Due to a multifactoriality, it is often difficult to identify the risk factors without a comprehensive diagnosis.

Methods. A comprehensive search of articles published in the last 20 years was conducted in four databases (PubMed®, Google Scholar, Web of Science and Scopus). Two independent researchers undertook a computerized research regarding the specific functional adaptation and musculoskeletal disorders in sports games with high prevalence of LBP. Different combinations of keywords LBP, muscle imbalance, muscle strength, muscle endurance, musculoskeletal disorders and the names of particular sports games (tennis, golf, volleyball, beach volleyball, handball, ice hockey, field hockey, floorball etc.) with Boolean operators and, or were used. The including criteria were full text in a scientific journal, study in English, and age between 13 and 40 years. Exclusive criteria were abstracts, other sports than sports games, other overuse pains. After establishing the criteria of selection 9 studies of 52 initially identified were analyzed.

Results. The sports games in association with a nature of the training are connected to specific functional adaptation and musculoskeletal disorders due to demands on musculoskeletal system, what might serve as a prerequisite for the overuse injuries and back pain syndromes [9; 6; 10; 11; 12; 13; 14].

As the most common functional parameters representing risk factors of back pain are analysed hip muscle imbalance together with, inter alia, pelvic asymmetry and lower flexibility of hip joints, spine flexibility and muscle endurance of trunk and core (table 2).

Table 2

Musculoskeletal Condition and Adaptation as the Predictors of Low Back Pain in Sports Games

Autors	**Problem**	**Sample**	**Methods**	**Results**
1	**2**	**3**	**4**	**5**
Abdelraouf, Abdel-aziem, 2016 [19]	Relationship between core endurance and LBP	55 male collegiate soccer, basketball, handball, and volley-ball players with non-specific LBP; 25 asym-ptomatic players (21,5±2,54 years)	Michele's Functional Scale McGill's core endurance tests	Significant differences in all tests (p<0,05) to detriment of the LBP group; n. s. correlation bet-ween MFS score and core endurance of LBP and non-LBP group; in LBP group negative correlation with the strength of trunk flexor and extensor (r = -0,54 resp. -0,79; p<0,05)
Bussey, 2009[15]	Prevalence of pelvic skeletal asymmetry in unilateral and bilateral athletes .	20 unilateral female field and ice hockey players, speed-skaters 20 bilateral bilateral athletes (triathlon, cross-country, scull-rowing 20 active non elite athletes	Electromagnetic tracking device with stylus (Polhemus fast treck and Polhemus Colchester, VT)	Difference in pelvic asymmetry between unilateral and bilateral athletes (p=0,001); Difference in pelvic asymmetry between unilateral athletes and non-elite athletes (p=0,01); n.s. differences between bilateral athletes and non-elite athletes (p=0,716).

End of the Table 2

1	2	3	4	5
Correira et al., 2016 [22]	Differences in trunk endurance, endurance time, and fatigue and activation in tennis players with and without LBP	28 male and 7 female tennis players 18,54±3 years 15 asymptomatic players; 13 sympto-matic players	McGill´s tests; Nordic Musculoskeletal Questionnaire; EMG	Greater flexor (*p* = 0,004) and right-side bridge endurance times (*p* = 0,043) in asymptomatic players LBP players a greater increase in avrEMG during the right-side bridge test for the left ES-I (*p* = 0,046) and right EO (*p* = 0,008).
Grosdent et al., 2014 [23]	Maximal isometric strength of trunk; pelvic and lumbar flexion of tennis players with LBP, without LBP and sedentary people	38 top tennis players; 11 without LBP (27,8±5,5 years); 27 with LBP (24,3± 5,9 years); 22 students (24,8± 4 years).	Tests of maximal isometric strength of trunk extensor, rotator, flexor and lateral flexor muscles (specific trunk dynamometers) Lumbar flexion mobility (inklinometer).	n.s. difference in trunk muscle strength and ratio or lumbar spine flexibility (all P>0,05) between LBP and non-LBP group. Tennis players in comparison to population sport-specific profile determined by a non-dominant trunk lateral flexor (p=0,02, F=4,05) and rotators (p=0,03, F=3,62) strength significantly higher than the dominant side.
Haag et al., 2016 [8]	Trunk endurance and a maximal strength of trunk stabilizers in players with LBP and without LBP	18 female ice hockey players from Bavarian League U15-U17 8 without LBP, 10 with LBP	Patients' history, physical examination, questionnaire, Y Balance Test (YBT), Swiss Olympic Test (SOT), maximum isometric strength of the trunk muscles	Participants without any LBP non-significant better performance in the SOT and the YBT. In the dynamic lateral isometric muscle strength test, patients without LBP had a statistically significant (p\0,05) better result than the other cohort.
Kujala et al., 1996 [9]	Lumbar mobility and occurrence of LBP in 33 non athletes) 34 ice hockey and soccer players;	Non-athletes (n=33); Ice hockey and soccer players (n=34); Figure skaters and gymnasts (n=31).	Questionnaire; modified Burton´s test	Predictors of low back pain: Male players participation in sport and low maximal lumbar flexion

End of the Table 2

1	2	3	4	5
	follow up (3 years): 29 athletes			Female players Decreased range of motion in the lower lumbar segment, low maximal lumbar extension, high body weight
Myrer et al., 2014 [21]	Changes in cross-sectional-area (CSA) of lumbar multifidus at the 4th and 5th vertebral level in players with LBP and without LBP; two seasons	12 collegiate volleyball players (19,3±1,3 years).	Ultrasound imaging (GE Logic e);	Significant decrease in lumbar multifidus m. CSA at the 5th vertebral level from 9,6±2,2 cm^2 to 9,1± 2,1 cm^2; p=0,05) in all players from preseason to postseason. Players with LBP sign. CSA m. multifidus also at the 4th vertebral level to compare to players without LBP (8,9±1,7 cm^2 resp. 9,4±1,9 cm^2).
Noormohammad-pour et al., 2016 [20]	Lateral abdominal muscle thickness and function, and cross sectional area (CSA) of lumbar multifidus (LM) in adolescent soccer players with and without LBP.	28 adolescent soccer players; 14 with and 14 without LBP, from the premier league (age 14,1±1,1/14,3±0,9 years)	The thickness of external oblique, internal oblique and transversus abdominis and the CSA of the LM muscles at L4 level on both sides at rest and contraction via ultrasound imaging (USI). Leg length discrepancy, hamstring flexibility, active lumbar forward flexion, and isometric muscle endurance of trunk extensors	No significant difference in baseline characteristics of participants between groups, no significant difference between LBP and non-LBP groups comparing all measured variables.
Vad et al., 2003 [16]	Correlation between hip internal rotation deficits and low back pain (LBP)	101 tennis players from the professional men's tennis tour (age 17–37 years) 40 with LBP	The finger-to-floor distance, lumbar extension, 90 ° abduction/internal rotation of shoulder, FABERE's distance, cross-chest distance, 90 ° flexion	LBP group a 7.6 ° deficit in hip internal rotation in the lead hip compared to the non-lead hip, a 3.2 ° difference for the asymptomatic group (p<0,05). In LBP group the difference in FABERE's distance

End of the Table 2

1	2	3	4	5
				8,6 cm comparing the lead and non-lead hip, asymptomatic group 3,2 cm (p<0,05}. Lumbar extension range in the symptomatic low back group 11,4 ° versus 20,3 ° for asymptomatic group (p<0,05). The difference in finger-to-floor distance not statistically significant (p=0,12).

Pelvic Skeletal Asymmetry

Pelvic muscle imbalances are produced by imbalance between muscles which control the pelvic inclination or the pelvis in the frontal plane (pelvic inclination). Pelvic asymmetry has been thought to alter the body mechanics, what leads to overload of bone and soft tissues. Such a danger occurs particularly in unilateral sports combined with increased spinal flexion and rotation. These include almost all sports games to a less or greater extent. This fact has been supported for example by the research results investigating the groups of female field hockey players, ice hockey players and speed-skaters in comparison with the active university women and with athletes of bilateral sports (triathlon, cross-country running, single skull rowing). Significant declines in structural asymmetry have been found in 15 unilateral athletes, 4 bilateral athletes and 6 active university women, out of 20 participants in each group. Unilateral overloading appears to be a significant predictor of presumable functional pelvic asymmetry. There is some evidence to suggest that asymmetric body movement patterns are linked to unilateral sports and pelvic asymmetry [15].

Hip Mobility Deficits

Equally, hip internal rotation deficits and lumbar range of motion deficits in athletes are considered to be a factor which increases the risk of back injuries and influences sport performance.

The reason is that the deficits in hip motion may result in negative musculoskeletal adaptation. Repetitive load and pivoting at the dominant hip, the cycle of microtrauma and scar formation might lead to capsular formation and reduction in range of motion. As a result, these may cause the overuse injuries, LBP and, eventually, poor performance [16]. This has been confirmed by the research of the aforementioned author in a group of tennis players. Deficits in lumbar extension significantly correlated with LBP. The deficit in hip internal rotation in the lead hip comparing to the non-lead hip was in the symptomatic group by 4,4°higher than in the asymptomatic group. Moreover, the symptomatic group showed smaller distance about by 5 cm between the knee and the mat on the preferred body side than on the non-preferred side of the body, when compared to the asymptomatic tennis players. Similarly, the difference in FABERE´s distance comparing the lead hip and non-lead hip was smaller by 5 cm in the symptomatic group than in the asymptomatic. Significant differences were also found in lumbar extension to the symptomatic tennis players´ disadvantage, but not in lumbar flexion, on the contrary. It suggests that low individual physiological maximum of lumbar extension may overload the lumbar spine of the athletes that perform the extension very often, what leads to the back pain.

Similarly, the correlation between deficiency in lumbar flexion and LBP has been partially confirmed by a three-year study of young athletes. At the beginning of the intervention the limited maximal lumbar flexion served as a predictor of the LBP to a certain extent. It comprised 16 % of variability between the asymptomatic and symptomatic players [9].

Trunk and Core Muscle Strength and Endurance

Speaking of the functional condition of musculoskeletal system, trunk muscle strength, including core muscles, is considered to be another risk factor of the back pain. The core muscles play an important role in the stabilization of the peripheral joints and reduce the risk of injury during intense physical activity. The core stability enables an athlete to maximize force production while minimizing loads placed on proximal joints. Ability to stabilise the core while performing dynamic movements of extremities together with the ability to absorb the repetitive load by the trunk, play the key role in all sport performance. This is especially important during complex movements such as running, jumping, throwing and hitting or kicking for example in volleyball, handball, basketball, soccer etc. [19].

In trained athletes, it acts as a feedback mechanism shortly before the beginning of the movement of the upper and lower extremities and is the basis for the realization of motor skills. Insufficient trunk control is proposed to be a contributing factor of the nonspecific LBP [17; 18]. The research results in this field, are however, not unequivocal. It has been supported for example in the supervised core-strengthening programme emphasizing the muscles of the trunk, spine and hip extensors in NCAA Division I collegiate basketball, volleyball and soccer players with LBP. The Programme did not have fully significant impact on the decrease in prevalence of LBP in both female and male players [17]. However, the test values of core muscle endurance in collegiate athletes (basketball, volleyball, handball and soccer players) indicate that the players suffering from LBP showed significantly lower trunk muscle endurance in comparison to asymptomatic athletes [9].

On the contrary, a poor correlation between LBP and abdominal muscle thickness and cross-sectional area of multifidus has been found in young soccer players. Similarly, there was non-significant difference between hamstring tightness and isometric muscle endurance of trunk extensors and active forward lumbar flexion between LBP and non LBP athletes [20]. Despite the aforementioned findings, the multifidus size as a risk factor of back pain cannot be completely excluded. On the other hand, the study examining female university volleyball players indicates a significant decrease in multifidus cross section area (CSA) at the 5th vertebral level in all the players throughout the season. Players with LBP showed significantly smaller multifidus CSA at the 4th vertebral level compared to players without LBP [21].

Insufficient strength endurance of the trunk muscles is of great importance in the occurrence of back pain, what has been indicated in quite a few studies. For instance, symptomatic players showed lower activation of extensor muscles, less co-contraction patterns and less abdominal endurance [22]. By contrast, the differences have not been found in maximal isometric strength of trunk muscles. When comparing trunk muscle profile in tennis players, no differences between the players with and without LBP were shown in maximal isometric strength of extensor, rotator, flexor and lateral flexor trunk muscles and lumbar spine flexibility.

In comparison to sedentary students, the tennis players showed a sport-specific profile determined by a significantly higher non-dominant lateral flexor and rotator strength than at the dominant side. That could result from the forehand and service actions which, that in righthanded players involve simultaneously left trunk rotators and lateral flexors, to generate more power [23].

Conclusion. In general, it would be unfounded to claim that the condition of musculoskeletal system in sports games acts as a risk factor of back pain, lumbar spine in particular, in all aspects. Most importantly, muscle imbalances together with functional asymmetry of pelvic and its asymmetrical rotation, which are produced by unilateral overloading, appear to be the key risk factor of back pain, as well as the low maximal lumbar flexion, particularly in association with low physiological maximum of lumbar flexion and extension.

On the other hand, the low level of strength endurance of trunk muscles, including core muscles, cannot be unambiguously considered a risk factor.

Similarly, maximal isometric strength of trunk muscles has not appeared to act as a risk factor of LBP either.

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References

1. 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. Nadler, S. F., Malanga, G. A., Bartoli, L. A., Feinberg, J. H., Prybicien, M., DePrince, M. *Hip muscle imbalance British Journal of Sports Medicine*, 37(3), 263–266.
2. Baranto, A., Hellström, M., Cederlund, C. G., Nyman R., Swärd, L. (2009). Back pain and MRI changes in the thoraco-lumbar spine of top athletes in four different sports: a 15-year follow-up study. *Knee Surgery, Sports Traumatology, Arthroscopy*, 17(9), 1125–1134.

3. Schulz, S., Lenz, S., Büttner-Janz, K. (2016). Severe back pain in elite athletes: a cross-sectional study on 929 top athletes of Germany. *European Spine Journal*, 25(4), 1204–1210.
4. Tunås, P., Nilstad, A., Myklebust, G. (2015). Low back pain in female elite football and handball players compared with an active control group. *Knee Surgery, Sports Traumatology, Arthroscopy*, 23(9), 2540–2547.
5. Patel, D. R., & Kinsella, E. (2017). Evaluation and management of lower back pain in young athletes. *Translational pediatrics*, 6(3), 225.
6. Widhe, T. (2001). Spine: posture, mobility and pain. A longitudinal study from childhood to adolescence. *European Spine Journal*, 10(2), 118–123.
7. Seminati, E., Minetti, A. E. (2013). Overuse in volleyball training/practice: A review on shoulder and spine-related injuries. *European journal of sport science*, 13(6), 732–743.
8. Haag, T. B., Schneider, A. S., Beckmann, C., Handel, M., Schneider, C., Mayer, H. M. (2016). *A test battery to investigate back pain in female soccer players. Sport Sciences for Health*, 12(3), 361–367.
9. Kujala, U. M., Taimela, S., Erkintalo, M., Salminen, J. J., Kaprio, J. (1996). Low-back pain in adolescent athletes. *Medicine and science in sports and exercise*, 28(2), 165–170.
10. Dillen, L. R., Bloom, N. J., Gombatto, S. P., Susco, T. M. (2008). Hip rotation range of motion in people with and without low back pain who participate in rotation-related sports. *Physical Therapy in Sport*, 9(2), 72–81.
11. Hoskins, W., Pollard, H., Daff, C., Odell, A., Garbutt, P., McHardy, A., Hardy, K., Dragasevic, G. (2009). Low back pain status in elite and semi-elite Australian football codes: a cross-sectional survey of football (soccer), Australian rules, rugby league, rugby union and non-athletic controls. *BMC Musculoskeletal Disorders*, 10(1), 38.
12. Purcell, L. (2009). Causes and prevention of low back pain in young athletes. *Paediatrics & child health*, 14(8), 533.
13. Pasanen, K., Rossi, M., Parkkari, J., Kannus, P., Heinonen, A., Tokola, K., Myklebust, G. (2016). Low back pain in young basketball and floorball players. *Clinical Journal of Sport Medicine*, 26(5), 376–380.
14. Pasanen, K., Rossi, M., Heinonen, A., Parkkari, J., Kannus, P. (2014). Low back pain in young team sport players: a retrospective study. *Br J Sports Med*, 48(7), 651–651.
15. Bussey, M. D. (2010). Does the demand for asymmetric functional lower body postures in lateral sports relate to structural asymmetry of the pelvis? *Journal of science and medicine in sport*, 13(3), 360–364.
16. Vad, V. B., Gebeh, A., Dines, D., Altchek, D., & Norris, B. (2003). Hip and shoulder internal rotation range of motion deficits in professional tennis players. *Journal of Science and Medicine in Sport*, 6(1), 71–75.
17. Nadler, S. F., Malanga, G. A., Bartoli, L. A., Feinberg, J. H., Prybicien, M., & DePrince, M. (2002). Hip muscle imbalance and low back pain in athletes: influence of core strengthening. *Medicine & Science in Sports & Exercise*, 34(1), 9–16.
18. Ezechieli, M., Siebert, C. H., Ettinger, M., Kieffer, O., Weißkopf, M., Miltner, O. (2013). Muscle strength of the lumbar spine in different sports. *Technology and health care*, 21(4), 379–386.
19. Abdelraouf, O. R., Abdel-aziem, A. A. (2016). The relationship between core endurance and back dysfunction in collegiate male athletes with and without nonspecific low back pain. *International journal of sports physical therapy*, 11(3), 337.
20. Noormohammadpour, P., Khezri, A. H., Linek, P., Mansournia, M. A., Hassannejad, A., Younesian, A., Farahbakhsh, F., Kordi, R. (2016). Comparison of lateral abdominal muscle thickness and cross sectional area of multifidus in adolescent soccer players with and without low back pain: a case control study. *Asian journal of sports medicine*, 7(4).
21. Myrer, J. W., Johnson, A. W., Neves, C., Bridges, J., Neves, T., Eggett, D. (2014). Multifidus size in Female Collegiate Volleyball Players from Preseason to Postseason and with Back Pain: 2949 Board# 235 May 30, 200 PM-330 PM. *Medicine & Science in Sports & Exercise*, 46(5s), 803.
22. Correia, J. P., Oliveira, R., Vaz, J. R., Silva, L., & Pezarat-Correia, P. (2016). Trunk muscle activation, fatigue and low back pain in tennis players. *Journal of science and medicine in sport*, 19(4), 311–316.
23. Grosdent, S., Demoulin, C., Souchet, M., Tomasella, M., Crielaard, J. M., Vanderthommen, M. (2015). Trunk muscle profile in elite tennis players with and without low back pain. *The Journal of sports medicine and physical fitness*, 55(11), 1354–1362.

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