Journal of the Anatomical Society of India 66 (2017) 127–130

Contents lists available at ScienceDirect

Journal of the Anatomical Society of India

journal homepage: www.elsevier.com/locate/jasi

Original Article

Effect of loading on occurrence of vertebral body changes in field hockey players

Mansoorehossadat Rozan[b,*], Vahid Rouhollahi[a], Dilip Kumar Dureha[b], Amit Rastogi[c]

[a] Department of Physical Education, Shahid Bahonar University of Kerman, Kerman, Iran
[b] Department of Physical Education, Banaras Hindu University, Varanasi 221005, Uttar Pradesh, India
[c] Department of Orthopedics, Medical Science Institute, Banaras Hindu University, Varanasi 221005, Uttar Pradesh, India

ARTICLE INFO

Article history:
Received 26 March 2017
Accepted 31 October 2017
Available online 8 November 2017

Keywords:
Vertebral body changes
Magnetic resonance imaging
Lumbar body index
Compression deformity ratio
Biconcave deformity ratio
Anterior wedge deformity ratio

ABSTRACT

Introduction: The purpose of this study was to assess the effects of loading on the deformation of the vertebral body of the lumbar vertebrae (L1-L5), which are subjected to considerable stress in field hockey players.
Methods: Relevant geometric variables measured by magnetic resonance imaging were compared between two groups of field hockey players. A total of 24 male field hockey players were enrolled in the study. The study participants were assigned to one of two groups, based on their experience with playing hockey: under 5 years, junior group; over 5 years, senior group.
Several geometric variables relevant to physical activity-specific stress were measured: lumbar body index, compression deformity ratio, biconcave deformity ratio, and anterior wedge deformity ratio.
Results: The results indicated a significant difference between the two groups with respect to the compression deformity ratio at three levels (L1, L2, and L4), and to the Lumbar body Index at two levels (L1, L2).
Discussion: Our data suggest that the mechanical loading on lower spine plays an important role in the development of degenerative changes of the vertebral body, which may be considered a risk factor for future injury and low back pain in hockey players.

1. Introduction

During sports activities, several important musculoskeletal structures are required to perform complex spinal movement patterns that involve bending and twisting at high speeds. Therefore, the spine is subject to the action of many forces, due to both physiological motion (flexion, extension, rotation, lateral flexion) and accessory motion (shearing tension, compression).[1] Depending on the direction, magnitude, and point of application of the forces, the spine may suffer deformation and injury. Abnormalities of the spine may also cause injury and pain among athletes because of the unique demands related to each specific sports activity. Lumbar spine injuries represent a significant concern to the athletes, coaches, and physicians.

During athletic endeavors, the lumbar spine is subjected to considerable stress due to unfavorable biomechanical situations typically occurring during such activities.[2] The thoracolumbar and lumbar spine are particularly susceptible to injury due to the large forces exerted in these regions, which are related to: body weight; loads created by motions such as flexion, extension, and rotation[3]; and loads created by accelerating motions especially in sports demanding high speed movements.

In athletes, independent variables that contribute, individually or in combination, to lumbar spine injury include poor technique, poor conditioning, and abnormal anatomy; thus, young athletes may have a spinal deformity that is incidentally or potentially related to their sports activities.[4,5]

Heavy physical work can lead to degenerative changes in the spine,[6,7] with body position being a factor that can dramatically affect the load on the lumbar spine. It was shown that the vertebral body undergoes a gradual change in shape under the application of a constant load.[8] Compressive damage arising from repetitive loading is most likely a common event in life; damage to the vertebral body causes decompression of the adjacent disc, leading to internal disc disruption and further degenerative changes.[9–11] Compression fractures can occur with axial loading in a flexed or vertical position. The capacity of the spine to resist injury is decreased if the forces applied involve flexion and are of long duration.[12]

* Corresponding author.
E-mail addresses: rozan.mansoore@gmail.com (M. Rozan), rouhollahi.vahid@gmail.com (V. Rouhollahi), dkdureha@gmail.com (D.K. Dureha), amitrastogibhu@gmail.com (A. Rastogi).

https://doi.org/10.1016/j.jasi.2017.10.011

It has been demonstrated that the load on the spine during physical activity can be measured based on changes in stature.[13] In analyses of force transmission and in model studies on the spine in high level athletes, it is necessary to estimate reference geometric parameters. It is particularly important to determine the size of the intervertebral discs, the size and shape of the vertebrae, and the overall shape of the spine.[14]

Besides the loads carried or lifted by the upper extremities, loads caused by specific, frequent movement during sports activities cause significant loading stress to the vertebral bodies, inducing continuous remodeling of the vertebrae. This leads to degeneration and deformities of the vertebral body, which is associated with increased risk of injury. In the case of the lumbar spine, loads due to flexion, extension, rotation, and acceleration are typically associated with deformity of the vertebral body.

To assess the potential deformation, the height of the vertebral body is measured in three places: at the anterior margin (Ha), at the posterior margin (Hp), and at halfway between these margins (Hm). Three types of vertebral deformities can then be defined based on these heights and on the anterior-posterior diameter (Dap) of the vertebral body. Thus, an anterior wedge deformity is characterized by a low Ha/Hp ratio; a biconcave deformity is characterized by a low Hm/Hp ratio; and a compression deformity is characterized by a low Hp/Dap ratio.[15]

The present study attempted to assess the effect of sports-related loading on the remodeling of the five lumbar vertebrae in male field hockey players, as predictive markers for future injury or lower back pain.

2. Materials and methods

2.1. Participants

For the purpose of this study, 24 male field hockey players (mean age = 22.25, standard deviation = 1.48) with and without symptoms of lumbar pain underwent a case history and a physical examination. The participants were classified in two groups: senior players, with $\geq$5 years of experience; and junior players, with $<$5 years of experience. The two groups were matched for sex and age. All participants provided informed consent before commencing the experiment. Players who underwent previous operation in their spine, and players with history of smoking habit were excluded from the study.

2.2. Measures

The pain description for each player was identified by a self-reported questionnaire and a physical examination conducted by an orthopedic specialist. The age, body height, mass, and the body mass index (BMI) of all the subjects were documented. No participant was medicated during the study. A dedicated 1.5 T MRI was performed by technicians for lateral views of the lumbar spine and sacral region of all participants.

The whole body of the vertebra was estimated on each image using Kinovea version 0.8.15 (Kinovea, France) and syngo fastView version 1.0 (Siemens, Munich, Germany), and all measurements were performed blinded to any other information or measurement regarding the subject (Fig. 1).

2.3. Procedures

After completing the imaging process, geometric variables were selected using the two referred software, including: lumbar body index (Hp/Ha ratio),[16] anterior wedge deformity (Ha/Hp ratio), biconcave deformity (Hm/Hp ratio), and compression deformity (Hp/Dap ratio).[15]

Fig. 1. Points of measurement of the anterior-posterior diameter (Dap), and of the heights for the anterior margin (Ha), posterior margin (Hp), and halfway between the two margins (Hm).

2.4. Statistical analysis

Data of outcome variables were tested using independent *t*-test for differences between the two selected groups. Data analysis was performed using SPSS version 17.0 (IBM, Chicago, Illinois, US), and level of significance was set as 0.05.

3. Results

Our findings showed that, between the senior and junior groups, there were no significant differences regarding age, weight, height, or BMI. This result suggests that these factors did not affect the results of the study.

The ratios, for both groups, of Hm/Hp, Ha/Hp ratio, and Hp/Dap for each level of the lumbar spine are shown in Table 1. Further, we observed significant differences between the senior and junior groups regarding Hp/Dap ratio at the spine levels L1 ($t = 2.36$, $p = 0.02$), L2 ($t = 2.35$, $p = 0.02$), and L4 ($t = 2.32$, $p = 0.03$) (Table 2), revealing that senior field hockey players exhibit greater compression deformity in these levels of the spine when compared to junior field hockey players.

Moreover, the senior field hockey players had significantly lower Lumbar body Index at L1 level ($t = 3.21$, $p = 0.004$) and L2 level ($t = 4.22$, $p <= 0.001$) when compared with the junior field hockey players.

On MRI examination, no significant difference between the two groups was observed regarding anterior wedge deformity or biconcave deformity and also no difference was found between the two groups of athletes with and without symptoms of lumbar pain

Table 1
Descriptive statistics of vertebral body measurements at each level of the lumbar spine (L1-L5) in senior and junior field hockey players.

Vertebral level	Group	N	Lumbar index		Ha/Hp ratio		Hm/Hp ratio		Hp/Dap ratio	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
L1	junior	12	1.180	.060	.876	.033	.861	.038	1.085	.026
	senior	12	1.113	.038	.846	.074	.833	.040	1.023	.086
L2	junior	12	1.166	.041	.886	.015	.826	.036	1.076	.044
	senior	12	1.093	.043	.870	.066	.831	.035	1.026	.058
L3	junior	12	1.056	.032	.960	.036	.838	.046	1.018	.029
	senior	12	1.048	.022	.931	.036	.839	.051	1.028	.069
L4	junior	12	1.036	.032	.983	.036	.863	.019	.936	.016
	senior	12	1.018	.032	.963	.049	.845	.036	.914	.029
L5	junior	12	.900	.102	1.126	.092	.870	.052	.845	.051
	senior	12	.890	.089	1.118	.063	.864	.081	.842	.027

Table 2
Comparison between senior and junior field hockey players with respect to vertebral body measurements at each level of the lumbar spine (L1-L5).

Vertebral level	Lumbar index		Ha/Hp ratio		Hm/Hp ratio		Hp/Dap ratio	
	t- value	P	t- value	P	t- value	P	t- value	P
L1	3.21	0.004	1.26	0.21	1.74	0.09	2.36	0.02
L2	4.22	<0.001	0.84	0.41	-0.34	0.73	2.35	0.02
L3	0.72	0.47	1.88	0.72	-0.04	0.96	-0.46	0.65
L4	1.39	0.17	1.13	0.27	1.47	0.15	2.32	0.03
L5	0.49	0.80	0.25	0.79	0.20	0.83	0.19	0.84

in relation to the criteria for degenerative changes that were used in this study.

The height of the vertebral body was measured in three places: at the anterior margin (Ha), at the posterior margin (Hp), and at halfway between these margins (Hm). Three types of vertebral deformities can be defined based on these heights and on the anterior-posterior diameter (Dap): anterior wedge deformity (low Ha/Hp ratio); biconcave deformity (low Hm/Hp ratio); and compression deformity (low Hp/Dap ratio). SD: standard deviation; N: number of participants in the group.

The height of the vertebral body was measured in three places: at the anterior margin (Ha), at the posterior margin (Hp), and at halfway between these margins (Hm). Three types of vertebral deformities can be defined based on these heights and on the anterior-posterior diameter (Dap): anterior wedge deformity (low Ha/Hp ratio); biconcave deformity (low Hm/Hp ratio); and compression deformity (low Hp/Dap ratio). P&HIPHEN;values lower than 0.05 were considered significant.

4. Discussion

High level sports participation in adolescents and young adults is associated with a greater incidence of low back pain and structural abnormalities, as revealed in imaging studies.[17] Back pain has significant effects on the athletes' performance, and is estimated to occur in 1.1% to 30% of athletes, with some variation depending on the type of sports activity.[18–21] Murtaugh[22] investigated the rates and types of injuries experienced by field hockey players and reported that low back was the most commonly injured region. Research done by Ogurkowska[23] proved that field hockey strongly affects the lumbar section of the spine. Pain in the spine is often difficult to diagnose. Loading appears to play an important role in the development of radiographic changes of the lumbar spine, and one factor that can dramatically affect the load on the lumbar spine is body position.[24] In the present study, we used MRI, which is considered the most accurate imaging modality for assessing the spine.[25] However, it is important to note that abnormal imaging findings are not always related to the source of the pain, as pathology can exist without pain, and vice versa. In the present study, we assessed degenerative changes related to vertebral body size and shape, which may be considered predictive markers for future lower back pain or injury.

Field invasive games such as field hockey create unique physiological and physical demands on spinal column of the players during playing and dribbling the ball which are usually executed in a position of spinal flexion. Lumbar spine injuries as a result of participation in field hockey have been reported in epidemiological studies.[22,26]

Such repetitive loading can create microscopic damage within a material or tissue, which gradually builds up until gross failure occurs. In living tissues, the process of damage accumulation is opposed by the process of adaptive remodeling.[15]

According to Alexander,[3] the type of injury that occurs in the lumbar spine, which is under significant stress in field hockey players, is dependent on the direction, magnitude, and the point of application of the forces in the spine. Ruyssen-Witrand et al.[27] proposed that vertebral size should be considered a potential independent risk factor for vertebral fracture.

Several studies have compared lumbar spine abnormalities of elite athletes with those in non-athletic groups with respect to various sports such as wrestling, soccer, tennis, track and field, and gymnastics.[28–30]

In this study, we focused on two groups with the same sex, range of age, and range of BMI, but with different experience with respect to playing field hockey. We hypothesized that, independently of other factors, more years of playing in field hockey-specific body positions and acceleration motions may cause more abnormalities in the lumbar spine. Indeed, we found that the vertebrae L1, L2, and L4 showed a significantly higher compression deformity in senior field hockey players. Likewise, L1 and L2 had lower Lumbar body Index in senior field hockey players. Thus, playing field hockey for more years appears to cause more loading on the lumbar spine, and deformity of the vertebral body.

Our result suggests that, in field hockey players, L1, L2and L4 are at higher risk of degenerative deformities and fractures, as they may be affected by compression and degenerative changes to a higher extent. Schmitt et al.[30] reported that the concavity index at

all levels of the lumbar spine was similar in different groups of track and field athletes.

Predisposing factors in field hockey include repetitive spinal flexion, extension, twisting, and loading. Poor development of abdominal musculature in conjunction with strong paraspinal muscles may increase the stress on the lumbar spine. On the other hand, Reilly and Seaton[31] observed an average spinal shrinkage rate of 0.4 mm/min in players dribbling a hockey ball. In proof to result of this study there were studies that showed changes in the shape of the vertebra in lower back of field hockey players.[5,23]

Reilly and Temple[32] demonstrated that an enhanced crouched position when dribbling accentuated the subjective and physical strain on the spine.

Additionally, several studies have reported that repetitive loading on the spine can cause the compressive failure of vertebral bodies.[33] In field hockey athletes must bend and rotate their bodies. The specific patterns of loading experienced by the field hockey players during dribbling, frequent flexion may explain the higher rate of radiographic changes we found for the vertebral body of L1, L2, and L4 in more experienced players.

No other significant differences were observed in our MRI examination of the lumbar spine with respect to anterior wedge deformity and biconcave deformity at any level, or lumbar body index and compression deformity of vertebrae L3 and L5.

The present study is limited due to its small population sample, and the fact that it did not account for factors like diet, quality of sleep, or the physical and mental condition of the participants.

In this study, we focused on loading on the lumbar spine caused by field hockey-specific body positions, which may translate into vertebral deformities and thus increase the risk of pain and spinal injury, and ultimately prevent the player from participating in sport events. Athletes with minor fractures in the lumbar vertebral body but without neurologic involvement may be considered to return to the sport competition, but under the supervision of the coach and physician; however, they should be made aware of the risks of future injury caused by the deformities. Coaches and athletes may consider these risk factors and apply proper training and conditioning to avoid the development of vertebral body deformities.

In general, athletes and coaches in sports that have an increased risk of lumbar spine injury should be educated in preventive techniques. Specific sport training may be considered to support this part of the spine, with the understanding that significant forces are transferred to the lumbar vertebrae, and with knowledge of the sport-specific deformation likely to occur at various spinal levels.

This observation requires more attention to be hypothesized as a risk factor for stress fractures in the future.

Conflict of interest

The all authors declare there is no conflict of interest.

Acknowledgements

The authors would like to thank the athletes who participated in this study, as well as the employees of the Orthopedics Department and the technicians of the MRI Centre at S.S. Hospital, Banaras Hindu University for their support with data collection. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

1. Cook J, Khan K. Spine and pelvis. In: McKeag DB, ed. *Handbook of Sports Medicine and Science: Basketball*. 1st ed. London: Blackwell Science Ltd; 2003:164–172.
2. Smith RM, Loschner C. Biomechanics feedback for rowing. *J Sports Sci*. 2002;20:783–791.
3. Alexander MJ. Biomechanical aspects of lumbar spine injuries in athletes: a review. *Can J Appl Sport Sci*. 1985;10:1–20.
4. d'Hemecourt PA, Hresko MT. Spinal deformity in young athletes. *Clin Sports Med*. 2012;31:441–451.
5. Rozan M, Rouhollahi V, Rastogi A, Dureha DK. Influence of physiological loading on the lumbar spine of national level athletes in different sports. *J Hum Kinetics*. 2016;50:115–123.
6. Tertti M, Paajanen H, Kujala UM, Alanen A, Salmi TT, Kormano M. Disc degeneration in young gymnasts: a magnetic resonance imaging study. *Am J Sports Med*. 1990;18:206–208.
7. Videman T, Nurminen M, Troup JDG. Lumbar spinal pathology in cadaveric material in relation to history of back pain, occupation, and physical loading. *Spine*. 1990;15:728–740.
8. Kazarian LE. Creep characteristics of the human spinal column. *Orthop Clin North Am*. 1975;6:3–18.
9. Crock HV. Internal disc disruption: a challenge to disc prolapses fifty years on. *Spine*. 1986;11:650–653.
10. Adams MA, Freeman BJ, Morrison HP, Nelson IW, Dolan P. Mechanical initiation of intervertebral disc degeneration. *Spine*. 2000;25:1625–1636.
11. Holm S, Holm AK, Ekström L, Karladani A, Hansson T. Experimental disc degeneration due to endplate injury. *J Spinal Disord Technol*. 2004;17:64–71.
12. Adams MA, Hutton WC. Prolapsed intervertebral disc: a hyperflexion injury 1981 volvo award in basic science. *Spine*. 1982;7:184–191.
13. Boocock MG, Reilly T, Linge K, Troup JDG. Fine measurement of stature for studying spinal loading. In: Reilly T, Watkins J, Borms J, eds. *Kinanthropometry III*. London: Spon (Verlag); 1986:98–103.
14. Ogurkowska MB. Pathological changes in lumbar-sacral intervertebral discs in professional rowers. *Biol Sport*. 2007;24:375–388.
15. Adams MA, Bogduk N, Burton K, Dolan P. *The Biomechanics of Back Pain*. 3rd ed. Edinburgh: Churchill Livingstone; 2013.
16. Smith LK, Weiss EL, Lehmkuhl LD. *Brunnstrom's Clinical Kinesiology*. 5th ed. Philadelphia: F. A. Davis; 1996:161–169.
17. Videman T, Sarna S, Battié MC, et al. The long-term effects of physical loading and exercise lifestyles on back-related symptoms, disability, and spinal pathology among men. *Spine*. 1995;20:699–709.
18. Hubbard DD. Injuries of the spine in children and adolescents. *Clin Orthop Relat Res*. 1974;100:56–65.
19. Micheli LJ. Back injuries in gymnastics. *Clin Sports Med*. 1965;4:85–93.
20. Dreisinger TE, Nelson B. Management of back pain in athletes. *Sports Med*. 1996;21:313–320.
21. Frank CB. Ligament healing: current knowledge and clinical applications. *J Am Acad Orthop Surg*. 1996;4:74–83.
22. Murtaugh K. Injury patterns among female field hockey players. *Med SciSports Exerc*. 2001;33:201–207.
23. Ogurkowska M, Kawalek K. Pathological changes in the lumbar intervertebral discs among professional field hockey players. *J Sports Med Phys Fitness*. 2016;56(1–2):85–91.
24. Dolan P, Earley M, Adams MA. Bending and compressive stresses acting on the lumbar spine during lifting activities. *J Biomech*. 1994;27:1237–1248.
25. Crewe H, Elliott B, Couanis G, Campbell A, Alderson J. The lumbar spine of the young cricket fast bowler: an MRI study. *J Sci Med Sport*. 2012;15:190–194.
26. Rishiraj N, Taunton JE, Niven B. Injury profile of elite under-21 age female field hockey players. *J Sports Med Phys Fitness*. 2009;49(1):71–77.
27. Ruyssen-Witrand A, Gossec L, Kolta S, Dougados M, Roux C. Vertebral dimensions as risk factor of vertebral fracture in osteoporotic patients: a systematic literature review. *Osteoporos Int*. 2007;18:1271–1278.
28. Jones DM, Tearse DS, el-Khoury GY, Kathol MH, Brandser EA. Radiographic abnormalities of the lumbar spine in college football players. A comparative analysis. *Am J Sports Med*. 1999;27:335–338.
29. Lundin O, Hellström M, Nilsson I, Swärd L. Back pain and radiological changes in the thoraco-lumbar spine of athletes: a long-term follow-up. *Scand J Med Sci Sports*. 2001;11:103–109.
30. Schmitt H, Dubljanin E, Schneider S, Schiltenwolf M. Radiographic changes in the lumbar spine in former elite athletes. *Spine*. 2004;29:2554–2559.
31. Reilly T, Seaton A. Physiological strain unique to field hockey. *J Sports Med Phys Fitness*. 1990;30:142–146.
32. Reilly T, Temple J. Some ergonomic consequences of playing field hockey. In: Lovesey EJ, ed. *Contemporary. Ergonomics*. London: Taylor & Francis; 1993:441–444.
33. Wolfram U, Wilke HJ, Zysset PK. Damage accumulation in vertebral trabecular bone depends on loading mode and direction. *J Biomech*. 2011;44:1164–1169.