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Prevalence and proposed mechanisms of chronic low back pain in baseball: part i

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Abstract

The prevalence of low back pain (LBP) among active baseball players ranges between 3 and 15%. The execution of baseball-specific manoeuvres, such as pitching or batting, may be related to the onset of LBP. These baseball motions are complex and require appropriate activation of the core musculature to produce a well-timed motion with forces minimized at the extremities. The spine, core and back musculature are involved with acceleration and deceleration of rotational motions. This narrative review synopsizes the available evidence of the prevalence of and mechanical factors underlying LBP in the baseball population. Possible mechanical mechanisms linking baseball play to LBP include aberrant motion, improper timing, high lumbar stress due to mechanical loading and lumbopelvic strength deficits. Potential clinical implications relating to these possible mechanical mechanisms will also be highlighted. The state of the evidence suggests that there are deficits in understanding the role of baseball motion and playing history in the development of spine conditions.

Keywords

Baseball; low back pain; kinematics; stress; injury

Introduction

The preponderance of research relating to baseball injuries has focused on the incidence and prevention of throwing arm injuries, as these are the most prevalent injury type in baseball players of all ages and skill levels (Dick et al., 2007; Hangai et al., 2009, 2010; Li et al., 2013; Posner, Cameron, Wolf, Belmont, & Owens, 2011; Schmidt et al., 2014). However, the lumbar spine is an understudied but pivotal link to the kinematic chain where the energy transfer occurs from the lower body to upper body during throwing and hitting (Young, Herring, Press, & Casazza, 1996). The execution of baseball-specific manoeuvres, such as

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pitching or batting, is complex and requires appropriate activation of the core musculature to produce a well-timed motion with forces minimized at the extremities. The spine, core and back musculature are involved with acceleration and deceleration of rotational motions. The movement of the pelvis and torso about the spine contribute 50% of the energy into throwing (Oliver & Keeley, 2010). In healthy players with adequate dynamic strength and appropriate execution of movement, the risk for low back pain (LBP) and non-contact injury is relatively low compared with reported non-contact upper and lower extremity injuries (Dick et al., 2007; Posner et al., 2011). LBP and/or injury may develop as a consequence of deficiencies in core muscle strength, uncoupling of the movement of the kinematic chain and biomechanical loading (Seroyer et al., 2010).

Currently there are approximately 19 million student-athletes and adults participating in organized baseball play (Dick et al. 2007b). Among collegiate and professional baseball players alone, low back injury rates range from 8.3% to 15%.; Dick et al., 2007 (Posner et al., 2011, 2011) Chronic LBP prevalence ranges from 1% to 40% of baseball players of all experience levels (Bono, 2004; P. A.; d'Hemecourt, Gerbino, & Micheli, 2000). LBP is a significant issue for the baseball player, as it contributes to missed participation time, disability and early career termination (Petering & Webb, 2011). Moreover, because baseball motions of throwing and batting involve whole body neuromuscular coordination, pain or injury to the low back can alter neuromuscular patterns of the upper body and subsequently contribute to secondary injuries elsewhere in the kinematic chain (Chaudhari, McKenzie, Pan, & Oñate, 2014). At present, there is not yet a synopsis of the potential mechanical factors that contribute to LBP and methods to address these factors. This focused, narrative review integrates the available evidence of the potential contributors to and prevalence of chronic LBP and acute on chronic low back injuries in baseball. Specific history questions during the clinical assessment are provided to guide the clinician on identification of mechanical issues underlying LBP.

Literature search

Relevant studies in English were identified through a literature search of MEDLINE and the Cochrane Database from 1990 to 2015. Reference lists of identified sources were also manually reviewed to obtain additional relevant sources. A literature search was conducted with the keywords including "baseball", "low back", "lumbar", "injury", "back injury", "epidemiology", "surveillance", "collegiate", "youth", "elite", "batting" and "pitcher". To supplement the information necessary to capture factors that may contribute to injury, the terms "biomechanics", "motion", "swing", "kinematics", "muscle strength", "kinematic chain", "rotation" and "core musculature" were used. A total of **1,270** articles were initially identified. These references were screened to determine whether or not evidence of LBP risk related to baseball play, potential injury mechanisms and methods to reduce LBP in this population was included. Papers were excluded if the content was not related to American-style baseball, did not include low back injuries, were in females, or described acute injuries. Using the levels of evidence from the Agency for Healthcare Research and Quality, U.S. Department of Health and Human Services, the papers presented in the epidemiology section next were categorized into Level 1 (randomized controlled trials), Level 2 (non-randomized controlled trials including prospective cohorts), Level 3 (observational studies with controls, case control studies), Level 4 (observational studies without controls) and opinion papers. Studies of cervical and thoracic spine and acute injuries without chronic onset were not included in this review.

Association of LBP in individuals with baseball playing history

A total of seven studies included specific LBP data in populations with baseball playing history (Dick et al., 2007; Earhart, Roberts, Roc, Gryzlo, & Hsu, 2012; Hangai et al., 2009, 2010; Ladenhauf, Fabricant, Grossman, Widmann, & Green, 2013; Li et al., 2013; Posner et al., 2011). Among these, three were Level III (Dick et al., 2007; Hangai et al., 2009; Posner et al., 2011) and three were Level IV (Earhart et al., 2012; Hangai et al., 2010; Li et al., 2013) evidence.

Adolescent players

Patterns of back pain are different in adolescent and high school athletes compared with adults (Purcell & Micheli, 2009). Skeletal immaturity coupled with exercise stressors can contribute to LBP and back injuries. High quality evidence in youth baseball players is limited. However, a retrospective study of a cohort of adolescents (mean age 13.9 ± 2.2 years) with symptomatic baseball participation was identified as the fourth most common sport identified, 8.9% of the patients being identified as baseball players, within the cohort of patients with spondylolysis (Ladenhauf et al., 2013). In other studies referenced by Ladenhauf et al., LBP frequency occurred in between 8.5% and 14.6% of youth baseball players (ages 12–15.5; Anderson, Sarwark, Conway, Logue, & Schafer, 2000; Blanda, Bethem, Moats, & Lew, 1993; Miller, Congeni, & Swanson, 2004).

Collegiate student-athletes

Hangai et al. (2009) conducted a cross-sectional study involving trained collegiate athletes (n = 308) and focused on the incidence of disc degeneration among these athletes. Baseball players have up to a 3.23 greater likelihood of being diagnosed with disc degeneration over non-athletes. This odds ratio ranks higher than athletes from other sports (not including football), such as volleyball, basketball and soccer (Hangai et al., 2009). In another cross-sectional study by Hangai et al. (2010), 4,667 new, non-varsity athlete university students were surveyed for their experience with LBP and the duration of which they may have played competitive sports when they were younger. The findings of the self-report survey revealed that those students who participated in competitive sports had higher prevalence of LBP than non-active students. Moreover, those students who had a long-duration sports experience (participated in sport from elementary school through high school) had the highest rates of LBP compared with students who had less sport experience. These students had a LBP prevalence rate of 71.7%. When examining LBP rates based on sport type, baseball was associated with the second highest LBP prevalence. Students who played baseball were 3.2 times more likely to experience LBP in their lifetime only behind volleyball which had an odds ratio of 3.8. The findings suggest that the asymmetric baseball postures and motions lead to asymmetric spondylosis in right and left sides and cause mechanical degeneration in intervertebral discs (Hangai et al., 2010).

Epidemiological data from the National Collegiate Athletic Association (NCAA) Surveillance System were derived from baseball players aged 16 years or older from the time frame of 1988–2004 (Dick et al., 2007). Among the three NCAA Divisions, the highest injury rate existed in Division I men's baseball, which may be due to a more accurate collection of injuries compared with Divisions II and III. Players were three times more likely to suffer an injury during a game than during practice. The trunk/back comprised 15% of the total injuries in collegiate baseball. The player activity/positions with the highest reported incidence of trunk/back injuries were the pitcher and batter (Dick et al., 2007).

Professional baseball players

Few studies have focused on the injuries incurred by Major League Baseball (MLB) players. One retrospective study of publically available data on MLB players found that disc herniation's occurred at a higher frequency during pitching and batting (27.6% and 38%) compared with players playing their position on the infield and in the outfield (20% and 14.4%; Earhart et al., 2012). Two additional retrospective studies gathered their data from publically available disabled lists and injury lists (Li et al., 2013; Posner et al., 2011). Posner et al. found that among the injured players, 7.8% and 7.4% of the fielders and pitchers, respectively, developed spine and back injuries. Other injuries in the structures that support the pelvis, hip and spine also occurred. For example, groin, hamstring and core injuries occur in 3.8–7.6% of players playing their position in the field and pitchers (Posner et al., 2011). Rates of back injury were similar between players that had been injured participating in games or practice (8.3% and 11.5%; Dick et al., 2007).

Injury types relevant to LBP in baseball players

Baseball throwing involves asymmetric spine loading, lateral bending and spinal flexion away from the throwing arm, and transverse plane motion to the opposite side with high rotational velocity. (Laudner et al., 2013) Evidence shows that sport motions that combine biomechanical stressors place significant loading on the vertebrae, including the pars interarticularis (Chosa, Totoribe, & Tajima, 2004; Crewe, Campbell, Elliott, & Alderson, 2013). Injury types that have a mechanical etiology include stress reactions and fractures, intervertebral disc degeneration and herniation, as well as strain of the lumbar region muscle/soft tissues. Injury severity is often dependent as to the chronicity of the current injury the player had sustained. Untreated chronic conditions have the potential to become a more significant injury, including stress fractures and spondylolysis.

Stress fractures

Stress reactions may occur as a consequence of overuse with repetitive mechanical stress that weakens the pars interarticularis and pedicles of the vertebrae. If untreated, stress reactions can lead to stress fractures and spondylolysis. Stress fractures (e.g. pars defects) occur in approximately 3.3% of high school baseball players (Changstrom, Brou, Khodaee, Braund, & Comstock, 2015). There is general agreement that repetitive motions involving lumbar rotation and extension promote spondylolysis.(Chosa et al., 2004; Pierre A. d'Hemecourt, Zurakowski, Kriemler, & Micheli, 2002; Laudner et al., 2013) There are case reports of pedicle stress reactions and stress fractures in adolescent pitchers.(Button &

Petron, 2007; Sairyo et al., 2003) Case series have reported development of painful pars defects in baseball pitchers serious enough to warrant surgical repair (Higashino et al., 2007). In some instances, LBP and spondylosis on one side may cause the contralateral side to absorb more stress during baseball motions, thereby leading to spondylolysis in the contralateral pars interarticularis (Tezuka, Sairyo, Sakai, & Dezawa, 2014).

Vertebral disc degeneration

Lumbar disc degeneration can be associated with chronic and recurrent LBP (Hancock et al., 2015). Among Japanese baseball players (19.8 ± 0.9 years of age), 59.7% of the sample had radiographic disc degeneration at one or more levels in the lumbar spine (Hangai et al., 2009). The majority of the degenerative processes occurred at levels L4/L5 and L5/S1 (57.9% of those with degeneration). The incidence of degeneration in baseball was highest of the sports studied, including swimming, basketball, kendo, soccer and running (Hangai et al., 2009).

Potential mechanical mechanisms underlying LBP

Baseball motions, such as throwing and hitting, involve high velocity, complex sequencing of body segment rotations that require substantial stability and motor control. The lumbar spine experiences large compression, shear and rotational moments (Stefanakis, Luo, Pollintine, Dolan, & Adams, 2014). Factors that interfere with this sequencing or stability and control include dynamic lumbar or core strength deficits, restricted range of motion (ROM) about the thoracolumbar spine, as well as improper timing of segment motions. Similar to other sports like golf, improper motion mechanics can magnify these forces and lead to LBP (Tsai et al., 2010). Figure 1 provides an overview of major mechanical risk factors that may lead to LBP if not properly addressed. It is likely that the development and persistence of LBP is bidirectional; as mechanical mechanisms contribute to pain onset, the presence of pain may also interfere with normal mechanics. These mechanical forces may accumulate gradually with long playing history and mechanical stress exposure such that the LBP becomes chronic or disabling.

Dynamic strength of core and hip

Dynamic stability of the low back is important for injury prevention. A stable low back and core permits the proximal musculature to contract against it to develop force to be transferred to the distal body segments during throwing and batting (Kibler, Press, & Sciascia, 2006). Core musculature can be described as a set of 29 pairs of muscles that stabilize the lumbopelvic region (spine and pelvis) as well as help assisting the transfer of energy up the kinetic chain (Faries & Greenwood, 2007). With LBP, the paraspinals and multifidus are involved and show signs of atrophy and fatty infiltration (Alaranta, Tallroth, Soukka, & Heliövaara, 1993; Kader, Wardlaw, & Smith, 2000; Pillastrini et al., 2015; Wallwork, Stanton, Freke, & Hides, 2009). Atrophied muscles have a delay in the contractile activity prior to spinal rotation (Hides, Richardson, & Jull, 1996; Hodges & Richardson, 1996; Kader et al., 2000). Maintenance of stability during normal movement and loading patterns of throwing or hitting would be challenged (Panjabi, 2003).

In the motion of a baseball swing, the trunk initially rotates posteriorly over the pelvis in preparation to swing, and then forward at ball contact and follow-through (shoulder-to-pelvis crossover). This crossover is believed to place high stress on the spinal viscoe-lastic structures (thoracolumbar fascia, ligaments, disc and capsule) and push the physiologic limits of these tissues (Gluck, Bendo, & Spivak, 2008). Players with inadequate dynamic strength to control rotation at high speeds may accrue microtrauma to these soft tissues, which leads to onset of LBP (Dennis, Finch, McIntosh, & Elliott, 2008).

Dynamic strength is particularly important during phases of the motions that involve a weight shift from 1 foot to the other, during one-legged support phases of movement and during rapid acceleration phases of segment rotations (MacWilliams, Choi, Perezous, Chao, & McFarland, 1998; Ohta et al., 2015). Core musculature needs to be appropriately activated to maintain lumbopelvic stability during the forward step in hitting or the transfer of body weight to the leading foot to follow-through during throwing (Tsai et al., 2010). In addition, trunk extension, which has been shown to be controlled by eccentric contraction of the hips and spine flexor muscles and thoracolumbar fascia, essentially prepares the muscles in expectancy of a pitch or throw (Watkins et al., 1989; Young, Casazza, Press, & Herring, 1998). Upon follow-through after release of the ball, the spine should be maximally flexed with the upper trunk rotated. In a similar fashion, when hitting there is pelvis and upper trunk rotation towards the pitcher immediately prior to ball contact, and after ball contact the trunk axial rotation increases towards the pitcher (G. S. Fleisig, Hsu, Fortenbaugh, Cordover, & Press, 2013).

Potential deficits in muscle activation in baseball players have been studied. Electromyographic studies of muscles that support the pelvis in baseball pitchers have revealed that the gluteus maximus and biceps femoris muscles of the trailing and stride legs during a pitch are activated at approximately 125–170% of the amplitude as during a maximal isometric contractile force (Campbell, Stodden, & Nixon, 2010). Among collegiate pitchers, approximately 50% of pitchers had poor lumbopelvic motor control as demonstrated by the inability to stabilize during hip external and internal rotation motion (Chaudhari et al., 2014).

Timing of kinematic events

The pitching motion involves several key segment rotational events that should occur within specific time frames of the pitching cycle (Seroyer et al., 2010). The throwing cycle can be defined from the point of lead foot contact (0%) with the ground to ball release (100%). Maximal pelvic angular velocity of ~400–700°/s occurs between 28% and 35% of the throwing motion. Upper torso maximal rotational velocity occurs at 47–53% of the throwing motion, with a separation between the two motions ranging from 18% to 22% of the throwing cycle (Fortenbaugh D., n.d.). Maximal trunk axial rotation should occur near foot contact; this point in the pitching cycle is also when maximal trunk translational acceleration peaks (G. S. Fleisig et al., 2013).

The bat swing cycle similarly has several key sequential segmental rotational events and may be defined as the point of lead foot ground contact (0%) to ball separation from the bat (100%). Between the swing cycle start and finish, other important timing points should be noted such as peak pelvis, trunk, shoulder and bat rotational velocities. There are no normative ranges for which these events occur. However, these events should occur sequentially along the kinematic chain with peak pelvic rotational velocity occurring first, then trunk, shoulder and finally bat. Maximal trunk axial angular acceleration in pitching (11,600°/s) and batting (7,200°/s) occur at lead foot contact and right after ball contact, respectively (Fleisig et al., 2013). The most physically challenging instant for the trunk and spine was found to be approximately at lead foot contact for pitching and after ball contact for batting (Fleisig, Chu, Weber, & Andrews, 2009; Fleisig et al., 2013). Early or late timing in the respective kinematic phases of throwing or hitting forces body segments distal in the kinematic chain to compensate and generate higher muscular forces to maintain overall ball or bat speed.

ROM and flexibility

ROM of the lumbar spine in flexion, extension, rotation and lateral bending may reveal issues that can lead to back pain (Purcell & Micheli, 2009). Athletes are subject to moving in all directions, however, common movements in baseball such as spinal flexion, rotation and lateral bending can shift focus of injury prevalence to potential ROM issues. Supporting muscles and connective tissues may affect the ROM of the spine. Limited hip and lumbar rotational and lateral motion may hinder performance but also be a cause of core strains during the high velocity movements of players. It should be noted that deficits or excessive ROM can contribute to the onset of musculoskeletal pain, however high amounts of flexibility and ROM can aid in performance.

Thoracolumbar ROM measurements of collegiate and minor league baseball pitchers are different compared with position players as well as general populations (Laudner et al., 2013). Pitchers have a significantly higher thoracolumbar rotational ROM to the non-throwing side as compared with their dominant throwing side (throwing side: 48.8°± 6.4° vs. **non-throwing side**: 51.9°± 6.6°; Laudner et al., 2013). Baseball players have larger passive trunk ROM for extension and rotation to both throwing and non-throwing sides compared with the normative numbers (American Medical Association, 2001).

Synopsis of the presented evidence

Existing evidence regarding LBP in baseball is derived from cross-sectional mixed samples of active people, previously active people and public sources. The actual prevalence of LBP and related spine injuries in collegiate and MLB populations may be underestimated due to the qualifications of the disabled list in professional baseball and the NCAA Surveillance System in collegiate baseball (Dick et al., 2007a; Changstrom et al., 2015). With respect to the qualifications of the MLB disabled list, there is not a requirement to place a player on the disabled list with an injury such as a muscle strain (potentially in the case of a player exhibiting LBP). Many times, players exhibiting symptoms such as LBP usually find that the issue resolves itself before a consideration of placing them on the disabled list presents itself. Hence, a player can miss time due to LBP symptoms and not have it reported because they did not get placed on the MLB disabled list. LBP symptoms are not characterized well within each study or are not consistently characterized among studies. Despite the relatively low quality of the evidence, it can be gleaned that the risk for lifetime incidence LBP is higher among persons who have played baseball compared with most other sports (Hangai et al., 2010; Schmidt et al., 2014). Moreover, long-term exposure to playing baseball was related to greater risk of developing LBP. Similar to other competitive sports, the risk for LBP and injury was greater during game play compared with practice.

Additional qualitative and quantitative data of these injuries including the intensity, type (sharp, aching, throbbing, intermittent) and specific region of the low back (e.g. sacroiliac joint, lumbar spine) would provide insight about the symptom burden and the specific areas at higher risk for injury in baseball players. Prospective evidence of LBP in baseball players is currently lacking. Prospective Level II studies of the incidence of lumbar spine injuries from preseason to the end of season would provide the temporal patterns of greater injury susceptibility. Documentation of pain onset, symptom severity and variations on training volume, type and/or time during the season would capture patterns of activity or stimuli related to worsening LBP. The importance of controlling LBP has major implications for independent living and maintenance of mobility. Although the careers of baseball players are finite, the lives of these players will continue past retirement. While baseball players have long lifespans (Abel & Kruger, 2005, 2006), they will also have a longer poorer quality of life due to baseball-related musculoskeletal degeneration with knee and finger arthritis being the two most reported (Dick et al., 2007; Meir, Weatherby, & Rolfe, 2007). As such, screening and prevention programmes LBP would provide important information for this population.

Conclusion

The available quantity and quality of evidence focusing on LBP and related injuries in baseball is low, but indicates up to 15% of players experience pain. (Dick et al., 2007) More serious injuries have been reported in baseball players pertaining to LBP, such as stress fractures and degenerative disc disease. Moreover, further research on this topic is needed to identify baseball activities that may specifically contribute to the pathology of LBP and other chronic low back injuries. Independent or coupled mechanisms such as aberrant motions, muscular strength deficits or suboptimal sequence of motion events may contribute LBP and related pathologies in the baseball population. Long-term tracking of performance, physical function and sport **motion with LBP is essential to** understand the pain impact on the player. Additional evidence of the activities that exacerbate or lessen LBP is needed to help players and their care teams develop specific treatment and training protocols.

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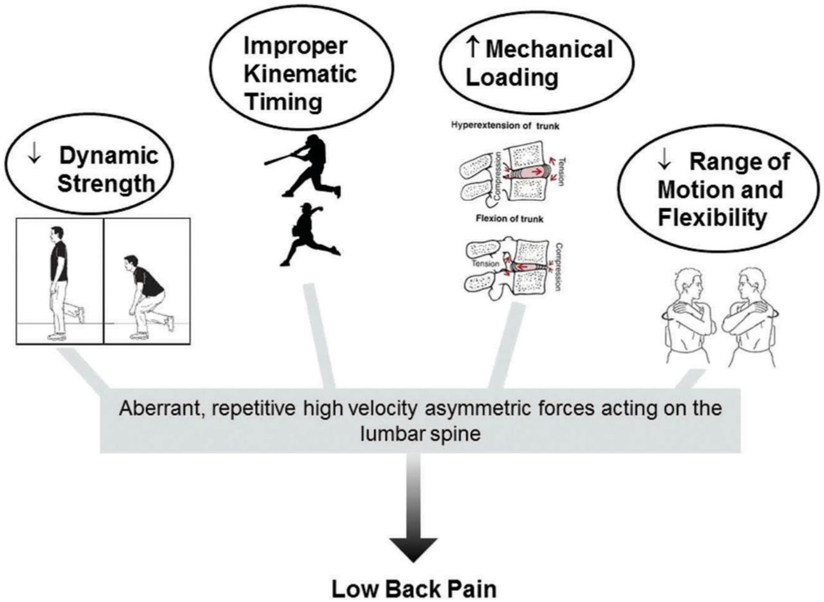

Figure 1.
Proposed key mechanisms of low back pain in baseball players.