SPINAL FLEXION IN SPORT

HELP OR HINDRANCE?

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THE PROPOSED ROLE OF SPINAL FLEXION FOR PAIN AND INJURY

The role of spinal flexion in low back pain has long been debated. With a decades long debate of whether permitting the spine to fully flex during lifting or sport activities tasks showing no signs of abating in the clinical literature – often providing conflicting opinions on the relationship between spinal flexion, pain and injury. At its simplest, our clinical question is whether spinal flexion is a hindrance to safe sport participation and whether athletes, coaches and therapists should devise training and intervention strategies to avoid or minimize spinal flexion during their sport. This narrative review will briefly review the relationship between spinal flexion and possible injury mechanisms via biomechanical and epidemiological research. Lumbar spine movement in the sagittal plane during a variety of sporting tasks will be reported and clinical recommendations for the management and prevention of low back pain from the literature will be discussed.

Biomechanical studies

Biomechanical research has helped elucidate possible injury mechanisms during the spinal flexion movement coupled with cyclic compressive loading primarily via in vitro studies. Researchers have shown that cadaver animal spinal functional units tend to demonstrate a greater susceptibility to injury of both the disc and the vertebral body when compressive loading is coupled with repeated spinal flexion[1]. Not untypical of previous and future research, Parkinson and Callaghan[1] exposed porcine, vertebral spinal units to varying conditions of loading coupled with repetitive flexion cycles. The authors documented that the posterior disc was the most likely site of damage during highly repetitive but low load conditions and if load was increased (>30% of the ultimate compressive tolerance) the more likely failure site of the spinal functional unit was the vertebral body. Gooyers et al[2] exposed porcine spinal functional units to 5000 compression loading cycles at loading levels of 10, 20 and 40% of the ultimate compressive tolerance (UCT), at different cycle rates (5, 10 and 30 cycles per minute) and through different ranges: 100% or 300% of the neutral zone. Of 123 specimens 24 were injured. 23/24 injuries were found in the 40% loading condition and ½ of all injuries were vertebral endplate fractures and 8/24 injuries were avulsions to the cranial endplate of the inferior vertebrae. 10/24 injuries occurred in the lowest repetition cycle of 5 cycles/minute. Within the 40% loading condition, posture and cycle rate did not influence the survival/damage of the specimens except when a more detailed histological examination was performed of the specimens. With this detail there was greater damage in the specimens in the 300% neutral zone movement condition. Of significance was that even in the low cycle rate with a minimal spinal range motion condition (100% of Neutral Zone) there were 7 fatigue injuries in the 40% UCT loading condition. This implies that minimizing spine flexion and even reducing frequency of loading is not wholly protective against fatigue failure.

Biomechanical research and in vitro studies at best can impart some idea of possible tissue sources of nociception due to potential tissue failure. However, tissue based in vitro studies would not reflect the inherent adaptability of a human biological system to imposed loading as the tissue studied is not alive and has no healing nor adaptive response associated with mechanotransduction. How these thresholds of tissue damage change in a living and an adapting human system is a question that has not been specifically answered.

Epidemiological Studies

While a potential mechanism of flexion related injury to specific structures has been shown in an animal model, epidemiological research does not consistently support spinal flexion as an independent risk factor for low back pain. For example, Coenen et al[3] prospectively linked the accumulation of low back loading with future low back pain with individuals lifting more than 25 kg, > 15 times per day when compared with individuals with no lifts of >25 kg. However, percentage of time in a flexed posture was not related to low back pain. With respect to an athletic population undergoing various levels of spinal flexion during their sport, Foss et al[4] conducted a 10 year prospective cohort study on the influence of specific spinal loading on low back pain in endurance athletes. There were no differences in low back pain amongst former athletes in cross country skiing (flexion loading), rowing (extension loading), orienteering (no specific direction) and controls. A risk factor for pain within the previous 12 months appeared to be higher levels of training volume.

An inherent limitation of biomechanical injury models is the axiom that nociception is insufficient for pain and that damage and degeneration is often poorly linked with pain. Thus, in vitro studies provide insight into possible tissue damage but may not accurately illustrate a pathway to the multi-dimensional creation of pain and disability that might influence sporting participation. However, these conflicts should not suggest that all spinal flexion is unrelated to pain nor that addressing or changing spinal kinematics is not a worthy intervention to address flexion-related pain in athletes.

The following section will document the role of flexion during various sporting activities with implications for the treatment of low back pain in athletes to follow.

SPINAL FLEXION IN SPORT

Rowing

Rowing is a predominantly sagittal plane sport movement that sees large degrees of spinal flexion and extension. The rowing stroke is composed of the catch, the drive and recovery. The catch phase occurs when the athlete has both maximal hip and spine flexion and is at the start of the drive phase of the rowing stroke. During the catch the lumbar spine is at its peak amount of total flexion and this value exceeds the maximal flexion found during a maximal forward bend while standing in 63-68% of elite rowers[5]. However, during the catch the pelvis is often in an anteriorly tilted position[6] which, to put in perspective relative to other training exercises, is the opposite of what would be found during a deep squat where the hips are in a similarly flexed position and the pelvis posteriorly rotated.

During the drive phase of rowing the pelvis begins to posteriorly rotate (i.e. which would tend to create entire lumbar spine flexion) while the upper lumbar spine is actively extending. Even though posterior pelvic tilt would tend to create spinal flexion, this is offset by greater lumbar spine extension thus the spine is in relatively less flexion at the end of the drive phase of the rowing stroke. At no time does the total spine position approach neutral during the drive phase – the spine remains in approximately 31 degrees of average spinal flexion at the end of the drive phase[5]. Of note, there is preliminary research showing that those with back pain tend to position their upper lumbar spine in a posture greater than 80% of peak flexion for a greater percentage of the time during the drive phase[7].

Cycling

Cycling demands a continuously flexed posture with little change in that position during the duration of the ride. Burnett et al[8] documented approximately

25 degrees of lower lumbar flexion (the angular difference between the 2nd sacral vertebra and the 3rd lumbar vertebra) and approximately 27 degrees of upper lumbar flexion (the angular difference between L3 and the 12th thoracic vertebra) during cycling in the dropped handlebar position. Total lumbar flexion would therefore be greater than 50 degrees. Of note, was the large variability between cyclists. What is not known is whether the postures adopted by the cyclists was close to their possible end range position. In a later study by Van Hoof et al[9] the relative position of the spine with respect to its maximal flexion angle was documented. These authors compared lower spinal flexion angles during a two hour cycling ride between subjects with pain and asymptomatic controls. The authors found that asymptomatic cyclists positioned their spine in approximately 63.6% of maximal flexion versus 74.1% of maximal flexion in the pain population.

Van Hoof et al[9] also showed that participants with non-specific lower back pain spent on average more than 38.5% of their cycling time in an end-range posture exceeding 80% of maximal flexion. This was contrasted with the asymptomatic controls that spent only 4% of their time in this end-range position. However, because the values presented were relative to the peak maximal spinal flexion range of motion during a seated forward bend test it is unknown whether the participants with low back pain had reduced peak lumbar flexion range of motion or whether they positioned themselves in an absolutely greater degree of flexion versus the control group.

Of clinical significance is that the low back pain participants reported that spinal flexion was a consistent aggravator of their low back pain. Yet they consistently adopted postures that mimicked this position and was correlated with pain onset.

Golf

Horan et al[10] showed that at the top of backswing there was minimal flexion of the thorax and anterior tilt of the pelvis. During the downswing the pelvis begins to posteriorly tilt rapidly (creating spine flexion) while the thorax first flexes and then extends before ball contact. Total spine flexion values were not reported in this study but Lyndsay and Horton[11] documented between 28.9-35.1 degrees of spinal flexion during the address position with a peak spinal flexion of 45.6-51.0 degrees that is assumed to occur during the downswing. Case studies in this authors lab have shown that the spinal flexion can be approximately 50% of the total spinal flexion range of motion available although the range is variable.

Running

MacWilliams et al[12] investigated lumbar and pelvis motion using implanted Kirschner wires into the spinous processes of healthy subjects during walking or running (self selected pace). The entire spinal range of motion (calculated as the angular difference between L1 and S1)

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during running averaged 4.7 degrees in the sagittal plane. Average pelvic motion demonstrated a range of motion of 6.1 degrees.. The general trend of spine motion during running sees an oscillation between a flexed posture at footstrike and an extended posture at toe off. The extension posture appears driven by an anterior pelvic tilt. The anterior pelvic tilt allows for increased thigh extension (extension of the thigh relative to an imaginary vertical line in the global reference frame) during running even though a similar degree or slightly increased hip extension (extension of the femur relative to the pelvis) is seen when compared with walking. Running demands increased range of motion in the sagittal plane of the lower lumbar spine when compared to walking but this increase in sagittal plane motion is not seen at the upper levels of the lumbar spine. In effect, the lower levels of the lumbar spine move with the pelvis and this movement is slowly attenuated as you move up the lumbar spine leading to less movement in the upper lumbar and thoracic spine.

Throwing like movements

Ranson et al[13] documented total spine motion using an electromagnetic tracking device in elite male cricket bowlers without low back pain. Bowlers were stratified into a side on/front on style of bowling or a mixed style. The pooled averaged peak flexion and extension range of motion during standing forward bend and re-extension was 67.5 and 29.0 degrees, respectively. During the bowling action athletes showed between 43.8 (side on/front on) and 52.7 (mixed) degrees of flexion depending on the style of bowl and 6.3 and 13.9 degrees of extension from neutral dependent on bowling style. Velocity of spinal flexion was averaged between 1012.0 (side on/front on) and 1412.0 (mixed) degrees/second. Spinal flexion velocity and total range of motion in the sagittal plane was greater than all other planes of movement.

Wagner et al[14] investigated the kinematics of the team-handball throw, tennis serve and volleyball spike. Lumbar spine extension angles of 10, 39 and 27 degrees were found for team handball throw, tennis serve and volleyball spike respectively. Specific spinal flexion angles were not provided quantitatively but in a graphic form that suggested approximately no more than 40 degrees of trunk flexion for the tennis serve and volleyball spike and less than 20 degrees of trunk flexion for the team handball throw.

Lifting

Potvin and McGill[15] compared lifting from the floor using a stoop (bending primarily at the spine) and a squat (bending primarily at the hips with minimal spinal bending) across a variety of loads (0-32 kg). The authors found approximately 51 degrees of lumbar flexion during the stoop and 40 degrees of lumbar spine flexion during the squat technique. Full spine flexion when measured during a maximal forward bend calibration trial showed a group average of 60.2 (7.1) degrees. The authors also modelled flexion just at L4/L5 and found average flexion values of 15.3 and 11.8 degrees for stoop and squat respectively. The authors considered approximately 17 degrees (range = 14-21) to be representative of the maximal flexion angle at the L4/L5 joint. A more dynamic analog of a lift is the kettlebell swing where McGill and Marshall (2012) documented 26 degrees of flexion at the beginning of the swing and 6 degrees of extension at the top despite instruction to keep a neutral spine during the task.

Kingma et al[16] measured spinal kinematics during different techniques to lift an object that did not fit between the legs. The authors evaluated the stoop, squat (bend primarily at the knees and hips while keep the spine straight and upright) and the weightlifters technique (a wide foot position and bend at the hip and knees while keeping an extended spine but not upright). Average peak lumbar spine flexion was 64, 52 and 45 degrees for the stoop, squat and weightlifters lift respectively.

IMPLICATIONS FOR MANAGING FLEXION RELATED LOW BACK PAIN IN SPORT

Clinical practice can driven by two philosophies for preventing and managing flexion related low back pain in athletes:

1. Symptom modification reasoned – athletes with flexion related pain should attempt to minimize or modify static

flexion or repeated flexion movements during their sport and training because the movement is painful and

2. Biomechanically reasoned – flexion under heavy loads or highly repetitive flexion should be minimized in all athletes regardless of pain as these positions and movements are associated with a potential biomechanical pathway to create injury in cadaver spinal motion units as demonstrated with in vitro and modelling studies.

The first pragmatic and common sense approach suggests that athletes with pain that is exacerbated by spinal flexion should modify their postures to avoid this aggravating activity. A new, less sensitive posture is taught during the sporting activity and during activities of daily living[7]. Physical functions/limitations (e.g. hip flexion range of motion) that might inhibit the maintenance of the new, less sensitive spinal posture would also be addressed. If a sensitized lumbar spine flexion position or movement cannot be avoided or modified during the athletic event (e.g. martial arts) then the athlete is advised to avoid the aggravating position during training (e.g. training the anterior abdominal wall via isometric activities versus resisted flexion) to "spare" the spine for the aggravating movement in competition[17].

It should be noted that this approach does not necessarily argue that the spinal flexion during the sport must be avoided forever. It assumes that the athlete has become sensitized to that position and movement due to a number of factors. Low back pain is a multidimensional problem and many areas of an athlete's life can be viewed as sensitising the spine and the nervous system. For example, poor sleep, worries about competition or beliefs about the fragility of the spine can easily increase the sensitivity of an athlete and make a once tolerated position/movement now uncomfortable. Changing the kinematics along with addressing the multidimensional, patient-specific presentation can work to desensitise the athlete. In time, especially if there are specific performance demands that require spinal flexion it may be permissible to allow the resumption of the previous kinematics.

Further, this symptom/sensitivity modification approach does not suggest that there is always an ideal spine position to perform the task. It merely recognizes that a certain position is sensitized and some modification that changes symptoms is appropriate. While there may be many cases where an athlete is sensitized to too much spinal flexion there can also be cases where an athlete adopts rigid, spinal flexion avoidance postures that also become sensitized. A tailored approach, that identifies the specific movement habits related to pain as well as the multidimensional contributors to sensitivity would be optimal.

The second approach is less reactive to the athlete's symptoms and assumes that athletic performance in the neutral spinal range is both less injurious, possibly less predictive of future pain and may have performance enhancing benefits[17]. This proactive approach would advocate that training the technique of the sport to avoid end range flexion or postures well outside of neutral is to be promoted regardless of the symptoms of the athlete. This approach is well supported by biomechanical studies showing a potential injury pathway with repeated spinal flexion and is consistent with much or current coaching wisdom and many biomechanical recommendations from researchers. However, little, if any, prospective epidemiological evidence exists to support this type of movement training for the prevention of low back pain in athletes.

It is expected that the tolerance to loaded flexion during sport and an individual athlete's adaptability would be extremely variable. This variability would no doubt make definitive conclusions difficult and would likely lead to mixed results in long term studies investigating the prospective role of spinal flexion in sport. Thus clinical recommendations in an uninjured population will be highly individual and may be best driven by performance goals rather than assumptions of ideal postures for injury reduction. A least harm but still highly debatable approach might recognise that flexion in sport is unavoidable and since repeated flexion under load may increase the risk of injury, athletes may want to avoid repeated heavy flexion loading during their activities of daily living and during supplemental training. For example, a golfer might require flexion and rotation during the golf swing and performs these activities repeatedly during their sport. During their conditioning for their sport they may want to minimise or monitor total training load into flexion and rotation or monitor spikes in training load of these specific movements but rather train the musculature in a neutral range with primarily isometric movements or exercises that minimise repeated spinal flexion. While the athlete is not training kinematically specific we can argue there is still a performance transfer to the goal task and perhaps little to no extra performance or injury prevention benefit comes from training a kinematically specific exercise.

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CONCLUSION

Repeated spinal flexion, often exceeding the neutral zone and approaching end-range flexion, is a common and necessary movement during many sports. However, individual variation does exist and altering spinal kinematics is possible. While a biomechanical association to spinal flexion mediated tissue damage has been documented there is less epidemiological evidence supporting this link. It is not unreasonable for coaches and therapists to consider decreasing the time spent in near end-range flexion but it is currently unknown if this will prevent injury or what level of flexion is permissible. Pragmatically, when an athlete has flexion related low back pain minimizing painful spinal flexion by changing sporting technique, activities of daily living habits and training technique along with addressing the multidimensional contributors to spinal pain can be beneficial.

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