Managing low back pain in rowers: can it teach us something about managing the general population?

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Over recent years, employers have increasingly facilitated, through equipment and education, the reduced need for their workforce to undertake lifting activities. This, however, does not seem to have correlated with the reduction of incidences of back pain in the working population; indeed it could be argued that this change in workplace activity has, instead, contributed to obesity and inactivity levels. While there is a high incidence of back pain in rowers, their ability to recover from this, and return fully to their activity enables us to further investigate the influence of loading activity on back pain and learn more about risk factors, prevention and rehabilitation techniques as related to the general population.

LEARNING OUTCOMES
TO SUPPORT PHYSIO FIRST QAP

1 Recognise the risk factors for low back pain.
2 Be aware of research with regard to the influence of loading on incidence of low back pain.
3 Explore the research on low back pain in rowers and how this may be related to treating and managing the condition in the general population.

Introduction

Low back pain (LBP) is ranked as the greatest contributor to disability worldwide, with a global point prevalence of 9.4%. In Western Europe the prevalence is 15% (Hoy *et al* 2014), and 12-month incidence range from 18.4% (Jacob 2006) to 3-5% (Papageurgiou *et al* 1996) depending on definition. Common risk factors include gender, occupation, obesity, smoking, socio-economic factors, physical activity (including lifting) and lifestyle. Over recent years, good quality research has shown that in a 12-month period, 30-50% of rowers will have an episode of low back pain (Wilson *et al* 2014). So rowing is clearly an activity that results in higher incidences of back pain than experienced by the general population.

Some of the previously mentioned risk factors for low back pain, such as smoking, obesity and inactivity, are largely absent in the rowing community, indicating that involvement in rowing is the direct cause of back pain in most rowers, rather than it being just the result of the human experience. There is a lack of good quality research examining the influence of biomechanics, including loading, on the incidence of LBP onset in the general population. The impact of confounding variables in the general population, including the factors already mentioned, which are not controlled, may over-emphasise the risk of activities such as lifting. This has raised questions regarding the relevance of the research into the biomechanical influences and has led many to question traditional ergonomic advice which recommends avoidance of lifting activities in an effort to avoid LBP. Indeed, workplaces have invested heavily in equipment and education, which facilitates avoidance of lifting in the workplace but, ironically, this is now associated with an increasingly obese and inactive workforce and has shown no change in the prevalence of LBP. Thus, rowers are a relevant population to study to investigate key questions around the influence of lifting on LBP.

The key observation in the research is that, while up to 50% of rowers may have an episode of LBP in a 12-month period, the majority do not and, of those who do sustain injury, most seem to recover fully to return to training and competition. Rowers' spines are required to go through hundreds of sequences of cyclical flexion during every session. At the point of maximum loading, their spines can reach 110% of full standing flexion range (Wilson *et al* 2013). Traditional ergonomic advice would flag such activity to be high risk for tissue failure leading to injury, yet this is not an inevitable occurrence in most rowers. So, what is it about rowers' spines that is different and what can we learn about risk of injury to the lower back, prevention of LBP and possibly rehabilitation techniques that can be applied to the average person with LBP?

This article reviews what is likely to contribute to onset of rowing LBP and

> "THERE ARE QUESTIONS REGARDING THE TRADITIONAL ADVICE RECOMMENDING AVOIDING LIFTING ACTIVITIES IN AN EFFORT TO AVOID LBP"

will examine why some rowers are more vulnerable to this than others. It will then present some preventive and rehabilitation techniques that are based on such findings. Understanding pain science is important in understanding LBP and it is acknowledged that this is part of the LBP picture. However, the emphasis of this article will be the biomechanical aspects.

Risk factors for back pain in rowing

While there is a paucity of well-constructed, prospective injury studies in rowing, a number of risk factors have been established (Wilson *et al* 2014). Previous history of back pain (Teitz *et al* 2003; Newlands *et al* 2015) and use of the rowing ergometer, i.e. land-based rowing machine training, particularly with regard to sessions lasting longer than 30 minutes (Wilson *et al* 2014; Teitz *et al* 2003; Newlands *et al* 2015) have shown to predict an episode of LBP. Additionally, it has been shown that the total training hours per month and age of the rower are also associated with an episode of pain, and this prevalence is increased with every year of rowing (Newlands *et al* 2015). Previous LBP history and increasing age are also established factors for LBP in the general population, but it seems that there is an activity type and threshold which increases risk for some rowers. The volume of loading that can be tolerated is likely to be individual; linking to the optimal loading "sweet spot" defined so well by Gabbett (2016). However, research suggests that higher volume is tolerated when associated with some specific kinematic variables. Understanding why the ergometer poses a higher risk to incidence of LBP than does rowing a boat on the water, requires some analysis of any differences in biomechanics occurring between these two activities.

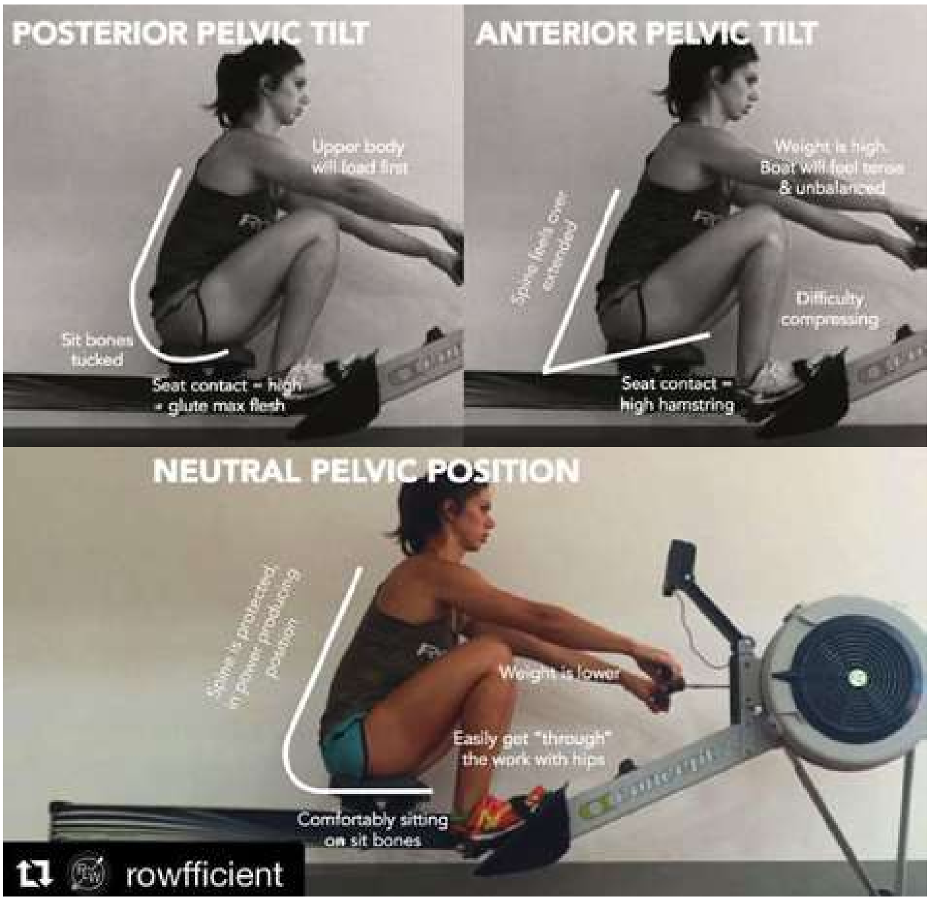

FIGURE 1: Optimal pelvic positioning at the catch position at the neutral pelvic position. Acknowledgement: Sara Hendershott, www.rowfficient.com

Spinal biomechanics and LBP in rowing

The rowing stroke is divided into two distinct phases; the "drive" and the "recovery". The drive is where the oar is in the water and effort is applied, and the recovery is when the oar is out of the water. The drive phase starts with the "catch" when the oar is placed into the water in a perpendicular position and the rower pulls; in this position the lumbar spine, hips, knees and ankles are fully flexed. At the end of the drive phase is the "finish" when the oar is removed from the water at the end of the stroke; in this position, the lumbar spine and hips are relatively extended (but still flexed) and the knees and ankles are extended. Put simply, the drive phase can be described as the "lifting" phase of the stroke.

LUMBO-PELVIC POSITIONING

Biomechanical analysis in the laboratory and on the water has shown that position of the pelvis has a crucial role to play in risk of injury to rowers (Holt *et al* 2003; Wilson *et al* 2012, 2013; McGregor *et al* 2002, 2005; 2007; Mackenzie *et al* 2008). A specific pattern of lumbo-pelvic motion is detected, with anterior rotation observed in the pelvis as the rower moves to the catch position, and posterior rotation seen at the finish position. This clarifies the idea that, particularly in the transition from drive to recovery, rowers should flex through the hips, rocking the trunk forward over the ischial tuberosities, keeping the lower back in a neutral position.

At the catch position, i.e. the point where load is applied, the pelvis should be vertical and the lumbar spine smoothly flexed. Figure 1 demonstrates the ideal position of the lumbo-pelvic complex in a neutral pelvic position.

Some key findings have been highlighted which may help to explain the difference of injury risk between rowers with a history of LBP and those with no back pain history. The technique of those with a history of LBP tends to deteriorate during a rowing session. This also applies to more novice rowers. They display a tendency to move through the lumbar spine rather than maintain good hip movement, which appears to load the spine unfavourably. Thus, it is crucial that lumbo-pelvic positioning is consistent, requiring excellent hip range of motion and good motor control, even under conditions of fatigue.

An interesting finding is that, as a rowing session continues, the mean response to cyclical flexion is for the lumbar spine to move into a more flexed position as the rower fatigues (Wilson *et al* 2013). This is known as "spinal creep" and has been well observed in many studies. Only a small number of studies have compared ergometer rowing to boat rowing, but one interesting finding may explain why the ergometer presents a greater risk of LBP; for rowing sessions of the same intensity and length of time, spinal creep is observed to be significantly greater on the ergometer when compared to a rowing session on water (Wilson *et al* 2013). This may be a reflection of the more forgiving nature of ergometer rowing when it comes to "bad technique".

SPINE POSTURE

Notably, throughout the rowing stroke and particularly at the point of maximum loading, the rower's spine is flexed in an extended "c" shape (figure 2) on a vertical pelvis.

> "IT IS CRUCIAL THAT LUMBO-PELVIC POSITIONING IS CONSISTENT, EVEN UNDER CONDITIONS OF FATIGUE"

This seems to defy conventional wisdom from ergonomic approaches that lifting should be performed with a straight spine. However, it is supported by biomechanical principles of loading. Aspden (1989) showed that curvature of the spine is necessary for its load-bearing function. The spine is considered as an arch with the load distributed evenly through segments; the arch collapses if a hinge forms, as it turns the structure into a "mechanism". This would be demonstrated if the spine was not smoothly curved and flexion was greater in one segment than another. The thrust line must be within the equilibrium and lie within the cross section of arch (figure 3).

Collapse of the arch can be prevented by tensile strength of tissues, but formation of hinges may lead to tissue damage. This would be noted when a rower's lumbar spine was inconsistently flexed and they were flexing through a hinge.

FIGURE 2: Catch position in rowing displaying vertical pelvis and smoothly curved spine with fully flexed hips and vertical shins

MUSCLE ACTIVITY

Research has shown that there is no difference in overall trunk strength between rowers and activity matched controls, although rowers exhibited higher EMG activity in their trunk extensors. In fact, rowing trunk activity is very much dominated by the posterior chain and activity of the spinal extensor muscles is high, and increases as intensity of the rowing motion continues, with spinal extensor muscle activity dominating the whole rowing stroke (Parkin *et al* 2001; Pollock *et al* 2009; Caldwell *et al* 2003).

Asymmetry of trunk muscles is common and may not be related to a sweep rower's, i.e. with both hands on just one oar, developed dominance, injury risk or history. Recent research (Martinez-Valdes *et al* 2018) has shown differences in extensor muscle recruitment between rowers with and without a history of LBP. Rowers with a history of LBP showed increased activation of trunk muscles with increasing load during an incremental test. Furthermore, muscle activity was displaced in a caudal direction towards the lower segments of the lumbar spine, which is likely to place the extensor muscles at a mechanical disadvantage. These rowers also showed decreased complexity of activity. Electromyography (EMG) signal complexity is related to additional fibre recruitment and has been associated with the time to endurance or time to task failure (Farina *et al* 2008). Therefore, both a reduction in complexity of EMG signals and an inadequate recruitment of muscle fibres could potentially intensify lumbar extensor muscle fatigability, thus increasing the chance of injury in the lower back region.

In a sport where the activity of the trunk

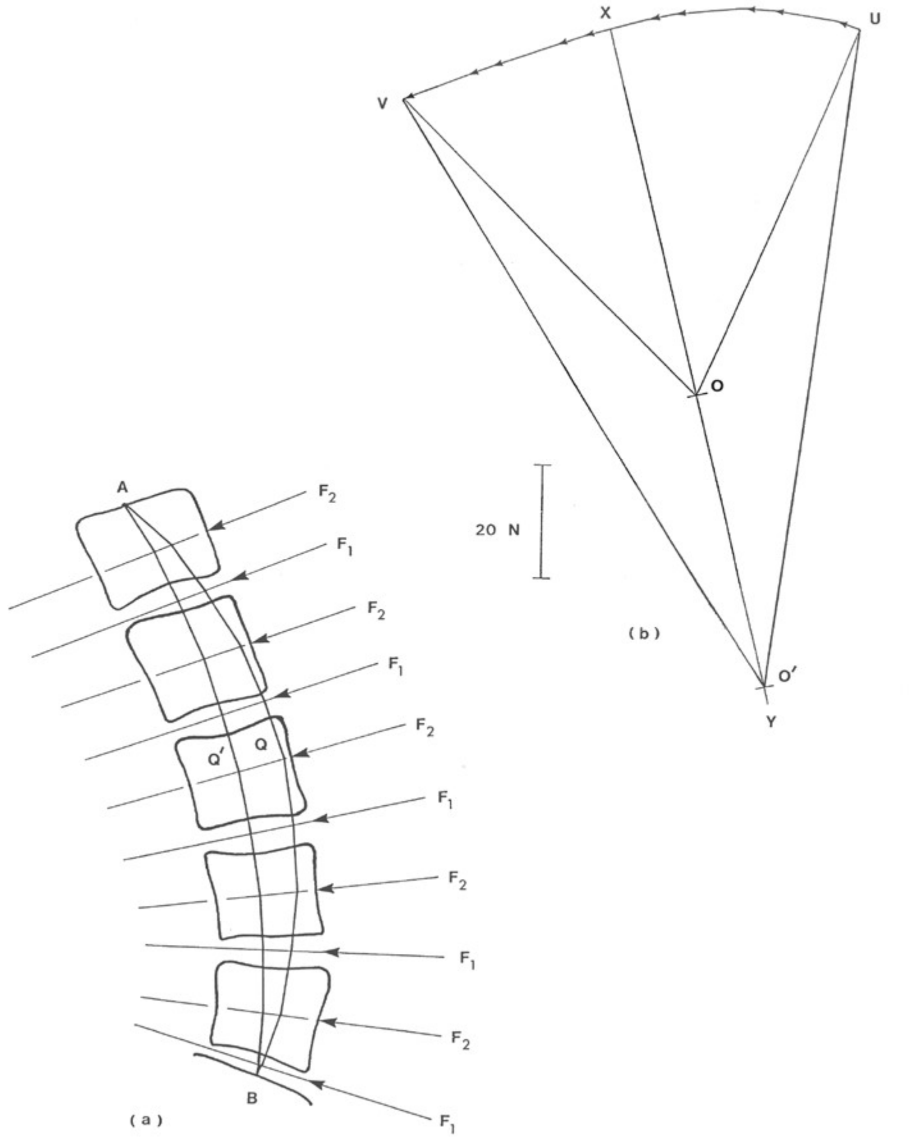

FIGURE 3: The lumbar spine in the normal erect posture. (a) A and B lie on the centre line of the arch formed by the vertebrae. AQB and AQ[1]B are thrust lines calculated from the force polygon (b), and correspond to positions of the pole O and O[1] respectively. (b) Only the first and last rays have been drawn from O and O[1] (Aspden 1989). Reproduced with permission.

> "ONLY A PROPORTION OF ROWERS DEVELOP LBP WHICH SUGGESTS THAT THE MAJORITY ADAPT WELL TO CYCLICAL LOADING"

is defined by cyclically active and relatively silent phases, dominated by the extensor group and characterised by low activity of the flexor group, traditional core stability training programmes which emphasise co-contraction of the trunk may not be appropriate. Indeed, one prospective injury study found that increased participation of core stability training increased the risk of LBP in rowers (Wilson *et al* 2010).

How do findings explain injury risk?

Studies have shown that lifting weights from the ground requires the lumbar spine to be flexed by 70-80% of full standing flexion, i.e. toe touching. This generates substantial tension in the non-contractile tissues of the back (Dolan & Adams 2001). Following an incremental rowing test, rowers were reported to reach 110% of full standing flexion (Wilson *et al* 2013). The mean intradiscal pressure at L4/5 was reported to be as high as 2.30MPa when lifting a 20kg weight with a "bent over round back", and a pressure of 0.83MPa when sitting with maximum lumbar flexion (Wilke *et al* 1999). Horizontal intradiscal pressure in sitting is reported at L4/5 as 1133kPa (Sato *et al* 1999), thus the loading sustained in rowers' lumbar tissues is considerable.

Rowers clearly achieve very high range of sagittal flexion, which is then combined with loading. This correlates with workplace studies, which have cited both of these factors as risk for low back injury (Marras *et al* 1993). Individually, these factors increase injury risk, but when they are combined, as in the case of rowers, the risk is increased further.

Repeated cyclical loading has been noted as a risk factor for lumbar spine injury in a number of previous studies (Hoogendoorn *et al* 2000; Marras *et al* 2006; Norman *et al* 1998). Cyclical loading induces "creep" in the viscoelastic tissues allowing an increase in initial range of motion and may increase risk of injury in a number of ways, for instance by desensitising the mechanoreceptors of the viscoelastic tissues, causing decreased muscle activity, instability and injury even before muscle fatigue sets in. Reflexive muscular stabilising forces in the lumbar muscles are compromised, also increasing risk of injury (Solomonow *et al* 1999).

Prolonged cyclical loading of the lumbar spine in flexion / extension not only elicits creep, but also causes significant increases in cytokines expression, resulting in acute inflammation for several hours after the activity. If the inflamed lumbar spine continues to be exposed to repetitive loading on a daily basis, this may lead to "conversion to chronic inflammation, degeneration of the viscoelastic tissues into fibrous non-functional tissue and the associated mechanical and neuromuscular disorders and loss of function" (Solomonow *et al* 2003; King *et al* 2009).

> **"RESEARCH IN ROWERS HIGHLIGHTS THAT THE SPINE HAS A GREAT CAPACITY FOR CYCLICAL LOADING"**

Elite rowers frequently row daily, which means that loading is indeed regular and sustained. This may help to explain the incidence of lumbar spine injury in the rowing population, but it also flags the capacity the spine has for cyclical loading. The inflammatory response can be regarded as an adaptive response to load which, if associated with adequate recovery, is an important part of building load capacity. Only a proportion of rowers develop LBP, which suggests that the majority recover and adapt well to such loading, and it is likely to be an important way of building a robust spine. Thus, it is likely that a sub-optimal loading pattern (Aspden 1989) imposes a load beyond reasonable tolerance, leading to tissue failure, which highlights the importance of good kinematics in rowing.

The fact that a previous episode of LBP in a rower increases their risk of a new episode may be explained by inadequate attention to possible risk factors such as sub-optimal loading patterning in rehabilitation, i.e. the rower returning to the same pattern once their LBP has settled, thereby imposing the same cycle of loading to possible failure. Those rowers who don't experience LBP are, of course, exposed to the same loading but in an optimal and tolerable pattern, and display a positive adaptation to loading as a result of adequate recovery.

Applying these findings to the general population

The research carried out in the rowing population highlights the great capacity the spine has for cyclical loading, and questions some of the current thinking around avoiding lifting to reduce risk of injury. It indicates that, while force vectors are likely to be different for lifting from standing, the spine appears to be resilient to repeated loading in a flexed position. When associated with good hip flexion, and accompanied by a well-functioning posterior chain group of muscles, distribution of a load through the spine appears to have only limited risk of development of LBP. However, capacity for loading should be built incrementally and should be accompanied by adequate time to recover and adapt. In rowers, risk of LBP has been reported to be higher at the beginning of winter training and in the transition to regatta season (Wilson *et al* 2013); times when there is a sudden increase in load. Appropriate kinematics and loading volume therefore not only allow a spine to tolerate cyclical loading, but also build a robust structure capable of generating great forces during rowing performance.

Exposure to load clearly prepares for work, yet the spine appears to be a structure for which this advice is avoided. Traditional concerns linked to findings of Nachemson's (1981) original trials, which examined intradiscal loading and highlighted "risks" of lifting due to high intradiscal pressures. Ergonomic advice to lift with a straight back and bent knees has been justified from anatomical input and research such as this. Rowers row with a flexed spine and this suggests that it is likely to be much more than positioning during loading which is the cause of back pain. Much further research in humans is needed to understand the role of tissue response, and associated inflammatory effect, to cyclical loading. Research in rowing suggests that this is very individual, albeit influenced by kinematics as well as recovery and adaptive capacity. It appears that cyclical loading is not only tolerated, but essential to build a spine which can function well. However, the loading "sweet spot" has not been identified yet and will vary for each person.

FIGURE 4a and 4b: The rowers' squat position

Rehabilitation approaches to rowing LBP

There is a lack of research examining preventive and rehabilitation approaches to LBP in rowers. However, findings can be extrapolated from some of the good biomechanics research that has been conducted to suggest some basic, but sound principles. This, of course, should also be accompanied by a good understanding of pain science and the biopsychosocial nature of LBP, which applies to elite athletes in the same way as any other individual.

PREVENTIVE AND SCREENING

As the point of the greatest loading is just after the catch, as the rower applies force to the oar, testing the ability of the rower to squat while keeping their heels relatively flat and the pelvis relatively vertical, assesses their ability to achieve good positioning (figures 4a / 4b).

Rowers who achieve sub-optimal positioning of their lumbo-pelvic complex during rowing, often struggle to squat without lifting their heels, or

FIGURE 5: The rower at the finish position

FIGURE 6: Eccentric and concentric control in the spinal extensors

may fall backwards. Other movements that should be flagged are those who are unable to keep the pelvis vertical and who move into posterior tilt early in the squat; this can be a reflection of poor motor control in the posterior chain, particularly the gluteal muscles, as well as inadequate range in the hips. A useful test is to ask the rower to move from sitting on a very low step with the pelvis vertical and the spine in a relaxed position, to standing without any sudden movement of the pelvis.

Rowing with good lumbo-pelvic positioning requires excellent range of motion (ROM) in the hip joint, and rowers should be able to achieve at least 130° of sagittal range (flexion) without movement of the spine or pelvis.

Rowers thus should be able to achieve a very deep squat through excellent hip range and with very good lumbo-pelvic control. Unlike many sports which would only train squats to 90°, rowers must train through deep loaded squats with feet close enough to be reflective of their position in a boat; this would train hip extension and trunk control from the limit of range, which is often avoided in a misguided effort to avoid injury.

Hamstring length is also important, not only to allow for the required ROM in the hip, but to also allow good positioning of the pelvis at the finish of the stroke. A simple test is to ask the rower to hold the finish position, displaying only a small amount of posterior pelvic tilt, maintaining flat legs, and with the feeling that they are still over their "sit bones" (figure 5).

It should be noted if the rower's knees pop up. This is due to tight hamstrings and may be a reason for a larger range of posterior pelvic tilt, which should also be flagged. The ability of the rower to hold this position well is also reflective of good motor control of the trunk musculature. It is one of the only parts of the stroke where the trunk flexors are notably active as they apply the braking force, as the trunk finishes one phase to move to another. A rower should be able to hold this position comfortably and to move, through hip extension only, from a vertical sitting position to a "lean back" with no pelvic tilting.

The ability to dissociate hip and spine movement is very important in rowing. It requires the ability to move through the hips while displaying very good eccentric to concentric control of the spinal extensors (figure 6). Again, the rower should be able to flex down and up, moving only through the hips, while keeping the trunk stable and the pelvis in a neutral position. Those with poor trunk control, particularly in the eccentric phase, will often collapse into greater spinal flexion accompanied by posterior pelvic tilt.

THERAPEUTIC

The general principles of triage, including screening for red flags, and best practice management should be applied to rowers. However, a few key principles are likely to lead to a better outcome. Early response to pain as well as management strategies that emphasise load reduction which usually includes the avoidance of water, and ergometer rowing for a short period, means that an episode of LBP can usually be managed quickly. Rowers need to be educated that rowing through pain is not beneficial. In an effort not to completely de-load the spine, however, active range of motion exercises and isometric activities, particularly of the extensors, are useful; there is emerging evidence that isometric contractions may help with pain relief. Screening tests as described earlier should be examined as part of the normal assessment, and can be used as rehabilitation tools. Poor hip range is a very common precursor for LBP onset in this group and should be addressed from the outset. Load and recovery strategies of the rower's training programme should be examined, and the coach should be consulted for input regarding modifiable technique errors that may be addressed. Return to the boat should be gradual with an emphasis on hip range, lumbo-pelvic control, and correction of rowing technique errors. Although an episode of LBP is predictive of future episodes, it is likely that alleviating the modifiable risk factors that can be addressed will attenuate this risk.

While this therapeutic approach is specific to rowing, it is likely to be very applicable to the general population, particularly those who are in occupations or other that require cyclical loading.

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