

Ergometer training volume and previous injury predict back pain in rowing; strategies for injury prevention and rehabilitation

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ABSTRACT

The most commonly reported injury site in rowers is the lower back. Research in recent years has focused on epidemiology and biomechanical analyses to try and understand mechanisms that contribute to this injury's onset. Injury surveillance mainly comprises retrospective questionnaires and reviews of medical records with a lack of prospective data. Of studies that reported 12-month data, the incidence of low back pain ranged from 31.8 to 51% of the cohort. Of the limited studies that specifically examined low back pain in rowers, (1) history of lumbar spine injury and (2) volume of ergometer training were the most significant risk factors for injury onset. Studies of technique on the rowing ergometer have indicated the importance of lumbopelvic rotation during rowing. Greater pelvic rotation at either end of the stroke is ideal—as opposed to lumbar flexion and extension; this tends to be poorly demonstrated in novice rowers on ergometers. Furthermore, technique can deteriorate with the demands of rowing intensity and duration, which puts the rower returning from injury at additional risk.

Rowing has evolved in terms of technique, training and equipment, particularly in the latter half of the 20th century. Modern boats are light and streamlined with hydrodynamics that optimise the forces generated by the rower. Modern oars increase the force the rower is able to apply in the water by reducing slippage and giving better purchase. Rowing is a sport that uses levers, so rowers are tall, strong individuals with long limbs relative to trunk size. Their muscles are predominately slow twitch fibres and their physiology is suited to endurance tasks.

Rowers complete high volumes of training, particularly at international level. Rowing training combines land and water activities that vary throughout the year. Land training emphasises rowing ergometer work although there are differences in kinematics between water and ergometer rowing. Assessment in rowing is difficult and rowing ergometer performance is frequently used in team selection and performance monitoring. For this reason, it remains a crucial part of the rower's training programme.

The biomechanics of rowing are complex and many variables contribute to the speed of the boat. A number of body segments must work simultaneously. High forces are generated at several specific points of loading on the rower's body. Owing to the cyclical movement pattern and high volume of training, these forces are repeated hundreds of

times during a typical training session. This combination of high forces acting on the rower, large training volume and type of training places the rower at risk of injury. The aim of this review is to examine factors associated with the onset of low back pain in rowers.

LOW BACK PAIN IN ROWING

The first stage in understanding an injury is a well-designed surveillance programme,¹ using a prospective cohort method. The most commonly cited injury identified through rowing surveillance is to the lumbar spine.^{2–12} However, the aim of any injury surveillance programme is not just to identify injury rates but also to establish predictors of injury and a number of studies have attempted to do this in rowing.

Studies of general injury profile in rowing

A search was carried out using a combination of the terms: *rowing, injury, rowers*. EMBASE, Pubmed, PEDro and AMED were searched. The final search was carried out in May 2014. No date or language limits were set. Two authors, (FW and AM) screened titles (initially) and abstracts and papers independently to decide inclusion. A third author (CG) was available where they may be disagreement. One hundred and sixty-four studies were accessed initially. Of these, the following were excluded: review papers/letters and editorials (38); studies of stress fractures only (26); studies that were not specific to rowing such as the use of rowing as rehabilitation in spinal cord injury (27); and studies of single injury in rowers (48). This left a small number of studies; of these, 11 were specifically studies of injury in rowing.^{2–12} Five studies used a retrospective questionnaire of injury rate,^{2–4 6 12} and three studies a retrospective review of athlete attendances at a sports injury clinic.^{5 8–10} Furthermore, the population group was frequently limited to elite rowers, most of whom were international standard at a specific training camp or international competition.^{2 4 7–12} These studies are summarised in [table 1](#).

The varied methodologies of the studies make comparisons inappropriate. Of the 11 studies, only 3 collected data prospectively and of those, only 2 studies^{6 11} reported the injury incidence/1000 h at 1.5 and 3.67, respectively. Of the 10 studies^{2–12} that reported location of injury, nine^{2–12} cited the lumbar spine as the most commonly reported site in rowing, ranging from 2.4% (of all sports) to 51% of injuries.

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Table 1 Summary of prospective and retrospective studies examining injury in rowers

Authors	Type of study	Sample size	Participants	Severity of injury measured?	Training and competition exposure measured?	Injury rate / 1000 h	Injuries classified?	Mechanism of injury reported?	Most common injury site	Factors associated with injury onset
Deveraux and Lachman ⁵	Prospective survey of clinic attendance, 2 years	1186	Recreational athletes	No	No	Not measured	Yes	No	Lumbar spine (2.4% of total)	Not measured
Budgett and Fuller ²	Retrospective survey of all injuries, 1 year.	69	International male rowers	Yes	Training estimated	0.4 (rowing) 4 (land)	Yes	Yes	Lumbar spine (51%)	Weight training
Reid <i>et al</i> ⁷	Retrospective survey of clinic attendance, 4 yrs	275	International female rowers	No	No	Not measured	Yes	Yes	Lumbar spine (25%)	Time of year and weight training
Boland and Hosea ³	Retrospective survey of all injuries, 3 years.	180	College male rowers	No	No	Not measured	Yes	No	Knee (25%)	Not measured
Edgar ¹⁰	Retrospective survey of clinic attendance, 5 weeks	44	International junior rowers	No	No	Not measured	Yes	No	Lumbar spine (30% of total)	Not reported
Coburn and Wajswelner ⁸	Retrospective survey of clinic attendance, 1 yr	54	Elite rowers	No	No	not measured	Yes	Yes	Lumbar spine (45% of total)	Weight training
Hickey <i>et al</i> ⁹	Retrospective survey of clinic attendance, 10 yrs	172	Elite rowers	No	No	Not measured	Yes	Yes	Chest (22.6%) female, Lumbar spine (25%) male	Time of year
Parkkari <i>et al</i> ⁶	Prospective survey of all injuries, 1 year	3363	General population	Yes	Classed as 'participation time'	1.5, 95% CI 0.6 to 3.9	Yes	Yes	Not reported	Not reported
Smoljanovic <i>et al</i> ⁴	Retrospective survey of all injuries, 1 year	398	International junior rowers	Yes	Yes	2.1 (training)	Yes	Yes	Lumbar spine (32.3%)	More than 7 training sessions/week
Wilson <i>et al</i> ¹¹	Prospective study of all injuries, 1 year	20	International male and female rowers	Yes	Yes	3.67	Yes	Yes	Lumbar spine (31.8% of total)	Ergometer training load.
Winzen <i>et al</i> ¹²	Retrospective survey of all injuries, 1 year	67	Elite male and female rowers	No	Yes	Not measured	Yes	Yes	Lumbar spine (50% of interviewees)	Not reported (reported as 'overuse')

While there is a need for additional, well-constructed, prospective injury surveillance in rowing, there is consensus that the most common injury is to the lumbar spine. Such data have more meaning when put in the context of reported incidence in the general population. Of the studies that reported 12-month incidence,^{1 2 4 8 12} the incidence of low back pain ranged from 32 to 51% of the cohort. The most recent systematic review of 12 month incidence of low back pain in the general population ranged from 6.3 to 15.4% (first ever episode) to 1.5 to 36% for 'first ever or recurrent episode'.¹³ So, the incidence of low back pain in rowers is likely to be higher than that of the general population, particularly when other risk factors for back pain, such as obesity and psychosocial factors, are taken into account.

Studies specifically examining lumbar spine injury

Few studies¹⁴⁻¹⁹ have specifically examined back pain in rowing. A common issue with all studies is the variation (or absence) of a clear definition of low back pain. Indeed this is observed in many other studies of low back pain, which is not surprising when it is considered that it is a symptom rather than a disease.

Bahr *et al*¹⁵ compared the prevalence of low back pain retrospectively in endurance athletes in several different sports. Over half (55%) of the rowers reported low back pain in the previous 12 months, which compared with 63% in skiing, 49.8% in orienteering and 47.5% in the control group. Of note, the rowers reported the most missed training sessions because of injury and the greatest number of injuries requiring hospitalisation compared to the other groups.

A survey carried out on a large cohort of intercollegiate rowers is limited in some aspects of methodology but permits some useful conclusions. Former intercollegiate rowers ($N=1632$) were surveyed to investigate training methods and back pain before and during college rowing.¹⁶ Thirty two percent of respondents reported back pain that developed during college rowing. Factors significantly associated with the development of back pain included age at the time of the survey; history of rowing before age 16; use of a hatchet oar; training with free weights, weight machines and ergometers; and ergometer training sessions lasting longer than 30 min.

Back pain was most likely to develop in the winter months (39% of cases) compared to spring (33%), autumn (25%) and summer (4%). This reflects previous research¹¹ and likely reflects the high volume of land training in winter. Many respondents associated the onset of back pain with a specific event; outdoor rowing was the most common at 72% of cases followed by weight lifting (50%) and ergometer training (29%). When training types were assessed, the only significant predictors of back pain for men were ergometer sessions that lasted longer than 30 min. Wilson *et al*¹¹ also found that time spent ergometer training was the most significant predictor of onset of low back pain. The 20-year period of this survey¹⁶ is probably its greatest limitation and data is subject to recall bias. Also, the response rate of 35% of 4680 athletes originally surveyed introduces a further risk of bias. However, it did highlight an aspect of training (more than 30 min of ergometer training) that is a predictor for back pain.

The initial study was followed up to examine if rowers who developed back pain in college are more likely than the general population to have back pain later in life.¹⁷ Those who had developed back pain in college had more subsequent back pain later (78.9% vs 37.9%), although the lifetime prevalence of back pain in former college rowers was no different to the general population. A further survey on the same cohort noted that participants who had previous back pain before rowing

were more likely to develop back pain during their college-rowing career than participants without pre-existing pain (57.1% vs 36.6%).¹⁸

Ng *et al*¹⁹ surveyed adolescent rowers and found a point prevalence of 64.5% (males) and 52.8% (females), compared to the mean point prevalence in the general population of 18.1%.¹³ In a self-report questionnaire, participants reported primary aggravating factors for low back pain as ergometer training, 'long row' sessions and sweep rowing (single oar rowing). This finding is in conflict with a previous study in adolescent rowers,⁴ which found no significant association between mean length of ergometer training sessions and low back pain. It is notable that studies in adolescent populations found a higher incidence of low back pain in males compared to females,^{4 19} with such gender differences not found in adult rowers.¹⁶

Although all these surveys were retrospective, they are the first to establish a profile of lumbar spine injury in rowers. The studies suggest that a number of factors such as volume of ergometer training and a history of low back pain may be associated with the onset of low back injury and raise questions regarding injury predictors. Studies in the general population²⁰ and the sporting population²¹ have also identified pre-existing back pain as one of the best predictors of future injury. There is an absence of investigation of other predictors in rowers; notably the influence of occupation. Many studies have examined international rowers, most of whom do not have another occupation. The influence of work-associated loading of the lumbar spine, combined with rowing stresses, merits research as this may identify modifiable factors, particularly in recreational rowers.

Mechanisms that may underpin rowing-related back pain

Low back pain is clearly associated with rowing, but what are the mechanisms behind this association? Highly repetitive rowing actions require high levels of consistency, coherence, accuracy and continuity. Additionally, the rower has to draw on physical strength and endurance, and translate this through skill and coordination into performance. A number of factors are proposed to relate to causation. These include rowing technique, the associated training (such as weight-training) and the use of the rowing ergometer, as well as other issues such as changes in the design and shape of the rowing oar.^{11 22-24} To solve this conundrum relies on knowledge of how a rower's body moves during the rowing stroke. There is a growing body of work exploring how understanding rowing kinematics can help prevent injury and enhance performance.²⁵⁻³¹

Research has been laboratory based with a focus on rowing ergometer technique. This has the advantage of controlling for external influencing factors such as wind speed, water condition, etc, as well as allowing exploration of factors such as fatigue, but does not reflect 'on-water' technique. A number of studies^{25 26 28 32} highlighted the importance of rotation of the pelvis on the hips as well as the rotation of the spine (lumbopelvic motion), showing that to achieve the extreme positions of the rowing stroke necessitates good anterior rotation of the pelvis rather than extreme flexion of the lumbar spine (catch position) and posterior rotation of the pelvis as opposed to hyperextension of the lumbar spine (finish position). Rowing technique deteriorates during continuous rowing leading to increased lumbar flexion²⁶ and frontal plane motion,³³ which is attributed to fatigue; although this could be dependent on rowing ability and experience. There is also an indication that the ergometer exaggerates these changes in technique compared to 'on-water' rowing.²⁹

Novice rowers use high levels of lumbar flexion with limited pelvic rotation, deteriorating further with higher work intensities.³⁰ While similar changes are seen in elite rowers, these are of a much lower magnitude.³¹ What is particularly interesting in both groups of athletes is the drive to maintain power output at the cost of technique. This has implications with respect to injury, particularly in an athlete returning to competition following injury or a young athlete attempting to gain a place in a highly competitive team.

The relationship between poor technique and injury is as yet unclear, although a study in international junior rowers⁴ showed that rowing experience (and thus enhanced skill) might reduce risk of injury in this group. Statistical modelling was able to use kinematic data to distinguish between rowers with and without a history of back pain.³⁴ Mathematical modelling of rowing has shown that lumbopelvic motion patterns do influence spinal loading, showing that poor lumbopelvic motion (an inability to rotate the pelvis and flex the lumbar spine in unity) is associated with higher loads and moments generation at L4/5 and L5/S1 (Buckeridge 2013—Imperial College London, PhD thesis). The challenges then remain as to how we can use this information to manage and prevent injury.

TRANSLATING EVIDENCE INTO PRACTICE

While it is clear that there is a limited evidence base to draw from, there are consistent predictors of injury. History of back pain predicts injury and can be identified in preseason screening of rowers. This would be particularly pertinent in those choosing rowing as a recreational activity. In those who are actively involved in the sport, appropriate prehabilitation and attenuation of other predictors (see ergometer below) could be instigated.

Another predictor of injury^{11 16} is use of the rowing ergometer, particularly for prolonged sessions (more than 30 min). The increased risk may be explained by evidence from kinematic analysis, which has shown that technique deteriorates with extended periods of ergometer use and high-intensity rowing, with a subsequent detrimental impact on spinal loading.^{26 30 31 33} Indeed in limited studies comparing lumbar motion on the water compared to an ergometer,²⁹ a different movement pattern was observed, which warrants further examination particularly in relation to its impact on spinal loading. Clearly, monitoring technique is important and the ability to perform this during water as well as ergometer sessions may prove to be invaluable to injury prevention and management. This may soon be possible with the current explosion in the development of wearable technologies and associated software. However, to date, none have undergone robust scientific evaluation.

Understanding kinematics and kinetics may aid understanding of injury onset. Changing how people move is difficult in any environment and there is a need to consider how to use research findings to steer training programmes. Clear messages regarding technique that focuses on body posture as well as force output needs to be conveyed. It is also clear that the main emphasis of research has been on lumbopelvic kinematics while there is a paucity of analysis of the mechanics of the lower limb and hip as well as analysis of muscle activity. It is likely that factors such as hip, knee and ankle joint function will influence loading at the lumbar spine, and a better understanding of this is required.

SUMMARY

Low back pain is the most commonly reported rowing injury. Ergometer training and history of injury are its strongest risk factors. Biomechanical analysis has shown that correct rowing

technique can have a strong influence on the loads placed on the spine and, as such, appropriate coaching and training in correct technique will have a role in reducing injury. Addressing modifiable factors such as training components (ergometer work and prolonged sessions) can reduce risk of injury. Screening of rowers should investigate previous injury and assess parameters that influence poor lumbopelvic technique, including hip flexor and hamstring flexibility and the function of muscles around the lumbopelvic region.

There is a need for further epidemiological research, with a particular emphasis on non-elite rowers. Future biomechanical analysis should address non-laboratory (water based) activity and whole body movement to enhance understanding of how forces act on the lumbar spine in a boat and explore how best to teach novice rowers correct technique.

What this paper adds

- ▶ Factors associated with onset of low back pain in rowers are history of injury and ergometer training volume (sessions longer than 30 min).
- ▶ Lumbopelvic motion should be considered when analysing trunk movement in rowing. Excessive use of lumbar flexion and extension without accompanying pelvic tilting may lead to increased lumbar spine loading.
- ▶ In rowing training and rehabilitation there is a need to consider endurance of the trunk muscles to facilitate good lumbopelvic rhythm. Factors such as fatigue, rowing intensity and skill level will also influence trunk control.

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