2010

Low back pain in schoolgirl rowers: Prevalence, bio-psycho-social factors and prevention

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School of Exercise, Biomedical and Health Sciences

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This thesis is presented for the degree of

Doctor of Philosophy

of

Edith Cowan University

March 2010

DECLARATION

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ACKNOWLEDGEMENTS

I would like to acknowledge the contribution of the following people, without whose help and guidance this thesis would not have reached completion.

Firstly and foremost, I would like to thank and acknowledge the contributions of my principal supervisor Dr Angus Burnett, and co-supervisor Dr Peter O'Sullivan whose counsel and support have been outstanding and will continue to inspire me into the future. I am indeed fortunate to have been supervised by them.

Secondly, my thanks to Chris Perkin and the team at Body Logic Physiotherapy whose commitment to the intervention program was greatly appreciated and continues to this day.

Thirdly, my thanks to all who assisted with data collection including Wim Dankaerts, Tim Mitchell, Lars Ankarberg, Megan Gooding, Rogier Nelis, Frank Offermann, Jannike Persson and Katherine Cheng for analysing the Child Behaviour Checklists.

Fourthly, I would like to acknowledge the Independent Girls' Schools' Sporting Association of Western Australia and John XXIII College for funding Studies I and II, Perth College for funding Study III, and all of the rowers who participated. Special thanks to the staff at Perth College who supported and assisted with this large project. I would also like to thank Gemma DeKnock, David Milne, Fiona Wilkinson, Clare Reeson, Allison Turner, Keith Reynolds and Dave Willmott who were the rowing co-ordinators from the participating schools.

Finally and importantly my thanks to my husband, family and friends who have supported and encouraged me through this journey.

ABSTRACT

Rowing is one of the largest participant sports on the Independent Girls' Schools Sporting Association (IGSSA) in Western Australia with approximately 400 participants competing every year. Rowing is an extra-curricular sport offered to girls 14 years of age and above, with these girls competing and training in both sweep and scull boats. Whilst the benefits of regular physical activity and exercise are well known, musculoskeletal problems have been documented in rowing. In particular, clinical evidence and previous research suggests that low back pain (LBP) is common in rowers. Adolescents who suffer from LBP are at an increased risk of recurrent and chronic LBP during adulthood therefore, this is a critical period to investigate the development of LBP. Therefore, the aim of this doctoral research was to examine LBP amongst the IGSSA rowing population in Western Australia. As the aetiology of LBP is known to be multi-factorial, the problem was investigated from a bio-psycho-social perspective. This thesis contains three studies with data collected over a two year period. These studies are described below.

In the first study, an investigation of the incidence of LBP and the levels of LBP and LBP-related disability for rowers and non-rowers was undertaken. Scoping data on self-reported factors that "bring on" or exacerbate LBP, training hours completed per week and boats most frequently rowed in was also collected in rowers. From this study, it was identified that there was a significantly higher prevalence of LBP in the group of 356 Schoolgirl rowers when compared with 496 non-rowing controls. Further, there was a significant difference evident for pain incidence between Year 9 and Year 10 rowers. Rowers also showed significantly greater pain and disability scores when compared with non-rowers. A number of self-reported rowing-related and habitual factors were associated with LBP in rowers.

The second study of this thesis investigated a sub-sample of Schoolgirl rowers from the first study. Specifically, rowers with LBP (N=30) and without LBP (N=30) participated in a cross-sectional study to determine the physical and psycho-social variables associated with LBP. In addition to measuring the levels of pain and disability in the rowers, this study examined physical factors such as static lumbo-pelvic postures, spinal proprioception, isometric back and lower limb muscle endurance, joint hypermobility, and the psycho-social factors of beliefs about back pain, fear of

movement with back pain, as well as the tendency for anxious and depressed behaviour. A secondary aim of the study was to classify the patterns of motor control impairment evident in those with LBP. The majority of the rowers were clinically classified with deficits in flexion or multi-directional segmental spinal control. Factors associated with LBP were reduced lower limb and back muscle endurance, and a general pattern for less accuracy and greater variability in lumbar spine repositioning sense.

In the final study of this thesis a non-randomised controlled trial was conducted to decrease the prevalence of LBP and associated levels of pain and disability in a group of Schoolgirl rowers. In this novel study an intervention group consisting of 90 schoolgirl rowers from one school and a control group consisting of 131 participants from three other schools were recruited. The multi-dimensional intervention strategy consisted of physiotherapy screening, prescription of individualised "specific exercise", follow up sessions, a back pain education talk and off-water strength and conditioning sessions. Primary outcome variables were collected for both the intervention and control groups at the commencement of rowing training, midway through the rowing season, at the completion of the rowing season and three months after the season had concluded. Primary outcome variables included the incidence of LBP and related levels of pain and disability whilst secondary outcome variables from the bio-psycho-social domain were measured at the start of the season and the end of the season in the intervention group only. From this study it was concluded that rowers have a high incidence of LBP but a multi-dimensional intervention program can be implemented to decrease the LBP incidence and the associated levels of pain and disability. Several secondary outcome variables considered to be of importance in LBP also significantly improved including physical fitness (aerobic conditioning, lower limb and back muscle endurance and sit and reach flexibility) and seated posture (usual and slump sitting). Further, improvements were seen in scores from the Child Behaviour Checklist.

This doctoral thesis has investigated a real world problem and has subsequently been used to formulate policy amongst the IGSSA schools in Western Australia. Further research is needed to determine the respective long-term results with respect to LBP and further randomised controlled studies are required to further validate the findings.

LIST OF PUBLICATIONS

Publications in Peer Reviewed Journals where Candidate was First Author

Perich D, Burnett A, O'Sullivan P. An examination of low back pain in adolescent schoolgirl rowers. *Submitted.*

Perich D, Burnett A, Dankaerts W, O'Sullivan P. Factors associated with low back pain and classification of motor control impairments in adolescent female rowers, *Submitted.*

Perich D, Burnett A, O'Sullivan P, Perkin C. Low back pain in adolescent female rowers: A multi-dimensional intervention study. In Press, *Knee Surgery, Sports Traumatology, Arthroscopy*.

Conference Presentations where Candidate was First Author

Perich D, Burnett A, O'Sullivan P. Low back pain and the factors associated with it: Examination of adolescent female rowers. In: Schwameder H, Srtutzenberger G, Fastenbauer V, Lidinger S, Muller E, ed. *XXIVth Symposium on Biomechanics in Sports*. Salzburg, Austria; 2006:355-358.

Perich D, Burnett A, O'Sullivan P, Perkin C. Low back pain in adolescent female rowers: A multidisciplinary intervention study. *In proceedings of 3rd Australian Association for Exercise and Sports Science Conference*, Melbourne, Australia, 2008:132.

LIST OF ABBREVIATIONS

AE	Absolute Error
CE	Constant Error
CTRL	Control
INT	Intervention
LBP	Low Back Pain
RE	Repositioning Error
SES	Socio-economic Status
VAS	Visual Analogue Scale
VE	Variable Error

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CHAPTER 1 – INTRODUCTION

Sections 1.1 to 1.4 of this chapter contain a review of the relevant background literature for the thesis. The first section (Section 1.1) provides a general description of rowing as a sport then the next section (Section 1.2) outlines the problem of low back pain (LBP) in rowing. In Section 1.3 there is a review of factors within a bio-psycho-social model that have previously been associated with LBP and factors that are potentially linked to LBP in rowing. In the final part of this review of literature (Section 1.4), due to the lack of LBP intervention studies in rowing, previous work that has addressed prevention of first-episode LBP and recurrent LBP in sports other than rowing and the general population is then outlined.

The rationale and specific aims of the studies contained within the thesis are detailed in Section 1.5 and the limitations of the studies are then stated in Section 1.6. Finally, a statement of the significance of the thesis is provided in Section 1.7.

1.1 THE SPORT OF ROWING AND IT'S BASIC MOVEMENT PATTERNS

The sport of rowing has a rich history of competition going back several hundred years and participation in the sport has steadily increased in recent decades[98]. Rowing is a unique sport in that; firstly, either one, two, four or eight participants can be seated in a rowing shell while performing the activity, secondly, the sport has different classes of racing which are determined by how many oars are used (sweep or scull), weight divisions (open weight and lightweight), and the presence/absence of a coxswain; and thirdly, the goal of the sport is to cover a set distance as fast as possible whilst going backwards. It is therefore not surprising that rowing requires a combination of technical skills, motor co-ordination, physical strength and cardio-vascular endurance[13]. Further, rowing involves high levels of teamwork as it is essential to have crew members working in unison for the boat to move in an optimum manner.

As briefly mentioned above the sport of rowing is divided into two broad styles of rowing they being sweep rowing (Figure 1.1a) and sculling (Figure 1.1b). In sweep rowing one oar per rower is used to propel the boat, and this oar is held in both hands and is positioned on either the strokeside (left or port side) or bowside (right or starboard) of the boat. The boat classes in sweep rowing consist of pairs, fours and eights. In sculling each rower uses two oars with one being held in each hand. Sculling is performed in singles, doubles or quadruples. Both sweep rowing and sculling involves repetitive flexion and extension of the trunk, however, sweep rowing has the additional demand of twisting the trunk at the catch. Whether sweeping or sculling each rower sits on a seat in the rowing shell which slides back and forth on tracks. The athlete's feet are secured in straps that are attached to a plate (foot stretcher) that is positioned at various angles for effective leg drive[12]. Throughout the pulling phase (or drive phase) the athlete pulls on the oar(s) which are held in an oar lock[98].

a) Sweep rowing

b). Sculling

Figure 1.1 The two different styles of rowing

The rowing stroke whether it be sweep or scull consists of four phases; the catch, drive, finish or release, and the recovery (Figure 1.2). At the catch the rower's knee joint and lower trunk show large amounts of flexion and the elbow joint is fully extended as the oar enters the water (Figure 1.2a). During the drive phase, the legs and trunk actively extend (Figure 1.2b). Rowers are taught to use the legs, trunk and arms in sequence to avoid the common mistake of bending the arms too quickly to pull the oars[98]. The drive phase is considered as the power phase of the stroke where the pulling force is executed by the extensors of the lower extremities and trunk, and the flexors of the upper extremities[28]. It is during this phase of the stroke that high levels of force are also generated by the rower on the foot stretchers[136]. Once the back extends, the arms flex, applying force at the oar handle with reactive forces being created at the oarlock and the water[136]. The oar's blade is therefore accelerated through the water. During sweep rowing the inside leg precedes the outside leg in the application of force on the foot stretcher, in the time of maximum force attainment and the termination of pressure[136]. In sweep boats the outside leg exerts greater force on the foot stretcher however, in sculling boats the application of force to the stretcher by each leg is roughly identical[136]. At the finish of the stroke, the elbows draw the blade through the water and the handle lightly brushes the abdomen, prompting the rower to "tap" the handle down slightly to remove the oar from the water (Figure 1.2c). The blade is then "feathered", or turned so that it is parallel to the water, so to decrease air resistance and therefore to be able to pass over the surface of the water and any waves easily. During the recovery the sequence of movement during the drive phase essentially reverses. It is during this last phase of the stroke that the knee joint again flexes as the athlete slides forward on the seat. Further, the hands carry the oar handle forward until the arms are extended, the trunk moves from an extended to a flexed position, to prepare for the catch (Figure 1.2d).

a). Catch b). Drive c). Finish d). Recovery

Figure 1.2 The different phases of the rowing stroke

1.2 THE INCIDENCE OF LBP IN ROWERS

Rowers are known to develop several types of injuries with lower back, ribs, shoulder, wrist and knee problems being reported[98]. It is clear however that low back pain (LBP) is common in rowers[13, 45, 49, 97, 105, 110, 111, 123, 135].

Table 1.1 summarises studies that have reported LBP/back injuries in rowers. LBP was first reported as a significant problem in rowers by Stallard[110] in a review of 29 adult rowers in the British National Squad of oarsmen and women with LBP. Further, Howell[49] found that 14 of 17 (82.4%) light-weight female rowers at a development camp responded positively to the question "do you have occasional or chronic low backache or discomfort?". However, these two previous studies which examined small samples[49, 110] made it difficult to attain an accurate reflection of the incidence of LBP in rowing. Hickey et al[45] retrospectively analysed injuries to elite rowers who were scholarship holders at the Australian Institute of Sport (84 females and 88 males) over a 10-year period from 1985 to 1994, and observed that injuries to the spine accounted for 15% of all female and 25% of all male injuries reported in rowing. Timm[124] assessed sacroiliac joint dysfunction as a possible source of LBP in elite rowers and found that this occurred in 54.1% of the rowers. Also of concern is the report of Teitz et al[123] who reported that the prevalence of back pain in intercollegiate rowers was high. In this study, surveys from 1632 (694 female and 946 male) former intercollegiate rowing athletes were analysed which contained questions relating to back pain and training methods before and during intercollegiate rowing. 32.9% of the females reported that they experienced college back pain and 31.7% of the males. The authors concluded that intercollegiate rowers from 1989 to 1998 were larger, started rowing at an earlier age, trained more intensely, and developed more back pain during college than the predecessors of 1979 to 1988. In addition, Wilson and associates[135] conducted a prospective cohort study over a 12 month period involving 20 (12 male and 8 female) International rowers competing as part of the Irish Amateur Rowing Union squad system. Rowers were interviewed monthly during the 2004/2005 rowing season to establish an injury profile for the sport. The most frequently injured area was the lumbar spine, accounting for 31.82% of the total injuries reported. Finally, a recent study of 398 (209 male and 184 female) international elite-level junior rowers competing at the 2007 Junior World Rowing Championships found low back injuries to be the most frequent complaint amongst this cohort (32.3% of all injuries)[105]. From

Table 1.1 Details of studies that have examined low back pain (LBP) / back injuries in rowers

Author(s)	No. of subjects and gender	Age	Performance level	Number(%) with LBP/ Injuries	Survey Period	Additional information
Stallard (1980)[110]	29 (exact gender split unknown but predominently men)	Unknown (Adult)	British national squad	29 (100%)	Physical examination by a physiotherapist over 5 year period	Inclusion criteria was rower was back injured 2 spondylolysis 3 recurrent lumbar strain 22 men with acute lumbar strain 2 women with acute lumbar strain
Howell (1984)[49]	17 (Female)	NA	United States national and international lightweight rowers	14 (82.8%)	Current musculoskeletal symptoms	Response to question "Do you have occasional or chronic low backache or discomfort?"
Hickey (1997)[45]	172 (84 Female, 88 Male)	Range = 14-36 yrs[a]	Scholarship holders at Australian Institute of Sport	31 (15.2% Females) 29 (25.0% Males)	10 consecutive years (1985-1994)	Females lumbar spine (15.2%) For males the regions most frequently injured were lumbar spine (25.0%), forearm/wrist (15.5%) The majority of the low back injuries were chronic (24 out of 29 in males; 19 out of 31 in females).
Timm (1999)[124]	98 (33 Female, 65 Male)	Mean (SD) = 23.6 (3.2)	United States Senior Rowing teams at 1995 Pan American Games and World Rowing Championships	Sacroiliac joint dysfunctions in 54.1% of team members	Current symptoms	Sacroiliac joint dysfunction was prevalent in both sweep rowers (66%) and scullers (34%).
Teitz et al (2002) [123]	1632 (694 Female, 946 Male, 2 Unknown)	20-30 yrs (N=441) 31-40 yrs (N=804) 41-45 yrs (N=383)	Former intercollegiate rowers	526 (32%)	20 Years (1978-1998)	Intercollegiate rowers in latter 10 years in this study were larger, started rowing at an earlier age, trained more intensely, and developed more back pain during college than the predecessors. Back pain was significant ending college rowing careers in 15.8% of the athletes (83 of 526). Results showed ergometer training for longer than 30 minutes was the most significant and consistent predictor of back pain for all age groups when all potential predictors were considered simultaneously.
Wilson et al (2008)[135]	20 (8 Female, 12 Male)	Mean (SD) = 26.25 (4.18) yrs	Irish international level rowers	31.8% of the total injuries reported	1 year (2003-2004 rowing season). Rowers interviewed monthly	The lumbar spine was the most frequently injured area of the body reported. Ergometer training was significantly associated with injury risk.
Smoljanovic et al (2009)[105]	398 (184 Female, 209 Male)	Median = 18 yrs Inter-quartile range of one year for both males and females	Participants at the 2007 Junior World Rowing Championships	55 Female (29.9%) 72 Male (32.3%) Total 127 (32.3%)	1 year (September 1, 2006 – August 2007)	This was a retrospective survey based on completion of a novel rowing-specific questionnaire and interviews.

[a] Average age at the start of scholarships was 20.1 years for females and 21.3 years for males

summarising the abovementioned studies it is clear that the extent to which LBP is a problem amongst schoolgirl rowers is unknown.

In the general population, LBP is a growing concern in adolescents and it is known that LBP prevalence increases with age, is more common in females, and there is a strong familial association[11]. Balague and associates[9] investigated a large population of children (n=1496) and documented a high prevalence of LBP (up to 34% in girls aged 14 years and over). Furthermore, it has been reported that there is an increased prevalence of back pain in the general population when girls are compared with boys[11, 99] If possible, it is important to prevent early episodes of LBP as onset of LBP in adolescence is considered to be a risk factor for LBP in late adolescence[103] and later in life[4, 21, 48]. With the non-trivial problem of LBP in adolescence, the extent and nature of LBP in schoolgirl rowers certainly requires further investigation.

Key Points

- LBP is common in rowers however, pain and disability levels have not yet been reported.
- The extent to which LBP exists amongst sub-groups of rowers such as schoolgirl participants is currently unknown.

1.3 LOW BACK PAIN IN ROWING – CONSIDERATION OF RISK FACTORS FROM A BIO-PSYCHO-SOCIAL PERSPECTIVE

Currently there is a paucity of research investigating LBP in rowers. Therefore, in addition to utilising knowledge from such studies, insight into the aetiology of LBP in rowers may be gained from previous research that has examined LBP in the general population or in other sporting activities.

The aetiology of LBP in the general population is known to be multi-factorial[2, 68] and it is now well accepted that LBP can be explained using a bio-psycho-social approach[130]. The bio-psycho-social model acknowledges that back pain may be aggravated by so called “biological” factors (such as mechanical loading, and individual functional deficits), psychological factors (eg. stress, depression and anxiety) and social factors such as those related to lifestyle, work, and how patients and society have learned to view back pain. The bio-psycho-social model of LBP has not been presented

as a causal model, but rather a cross-section of the clinical presentation at one point in time[91, 130].

To date, all domains related to the bio-psycho-social model have not been investigated in sporting-related LBP. Rather, biological factors such as mechanical loading patterns that are considered to lead to sporting injuries have been the main focus of previous investigations[18, 19, 92]. Factors within the bio-psycho-social domain that are known to be associated with LBP are discussed below with reference to the general population and sport in general. Rowing-related examples are provided where possible.

1.3.1 Biological Factors

1.3.1.1 Mechanical Loading Patterns Related to Rowing and Other Sports

A knowledge of mechanical loading patterns is fundamental in determining the aetiology of LBP is sport[18, 19, 92, 94]. In rowing there are distinct types of mechanical loading patterns that have the potential to cause LBP or exacerbate pre-existing LBP. These loading patterns include those experienced whilst sculling (flexion and compression), those experienced in sweep rowing (flexion, rotation and compression) and flexion/extension cyclic loading from the beginning to the end of the row stroke which is common to both sweep and scull rowing.

Rowing is a seated sport that is typified by repeated and prolonged flexion of the lumbar spine. From research investigating ergometer rowing[23] and anecdotal statements discussing on-water rowing[98, 110] it is known that flexion of the lumbar spine/lower trunk is maximised at the catch and it has been reported that the lumbar spine is flexed for approximately 70% of the stroke cycle[94]. A study conducted by Caldwell and associates[23] that examined male and female high school rowers showed that high levels of lumbar flexion were attained during the rowing stroke and these increased throughout the duration of a rowing trial conducted on an ergometer. This finding is supported by a recent study that was conducted on a Concept II rowing ergometer. Ng and associates[79] reported that rowers with a flexion-classification of LBP (see Section 1.4.2 for further discussion on classification of LBP) postured the lumbar spine in flexion for a greater proportion of the drive phase and were nearer to end range flexion when compared with rowers without LBP.

With rowing being a seated sport, the compressive loads due to sitting are of interest. It has been previously reported that compressive forces on the lumbar spine at L4/L5 in unsupported sitting may be in the order of 2.5 times body weight[24]. This would

effectively be the minimum magnitude of compressive force that may be experienced in rowing, as additional compressive forces are caused by; firstly, the spine being flexed for a majority of the drive phase and secondly, high forces being achieved through pulling the oar through the water and these forces being transferred to the lumbar spine. Consequently, it is not surprising that compressive forces at L4/L5 have been calculated to be 4.6 times the rower's body mass during a 2000m race simulation on an ergometer[76]. Further, Smith and associates[104] in recent research investigating elite males rowing on various ergometers (Concept II fixed, Concept II sliding and RowPerfect) found that mean compressive forces ranged between 3220-3670N for the three conditions at the catch and these forces markedly increased up to mid-drive phase. The combination of flexion with compressive loading has been identified from cadaver studies as a potential mechanism of injury to structures of the lumbar spine such as the facet joints, intervertebral discs and posterior ligaments[94, 102].

In comparison to sculling, there are few studies that have examined mechanical loading patterns in sweep rowing. Rumball et al[98] in their review of rowing injuries suggested that in sweep rowing, hyper-flexion and twisting forces are exacerbated at the catch position, and high (unspecified) loads are created on the spine as the blade drives through the water. The addition of rotation to the spinal segment that is at its end-range flexion may result in increased tissue loading of passive spinal structures (bone, ligament and disc) as there is less compliance to movement at the end range of flexion[20]. Further, Shirazi-Adi[102] in his research using finite element models suggested that when large compressive loads are combined with large forward flexion and rotational loads, there is the potential to damage the intervertebral discs[102]. Also, it has been suggested that sub-maximal flexion increases the available range of axial rotation[20, 90]. Therefore, when the spine is rotated or loaded within a more neutral position of a motion segment, there is more compliance within the passive spinal structures, thereby potentially reducing the risk of injury to these structures.

It is possible that there are gender-related mechanical issues that are relevant to the study of LBP in rowing. Hosea and colleagues[46] proposed that increased forces on the lumbar spine may be evident in male rowers thereby accounting for a greater incidence of LBP in male rowers when compared with females[45, 105]. Furthermore, a study by Ng et al[78] illustrated that males tended to row with a more 'slouched' thoracic posture in addition to a greater posterior pelvic tilt which may result in increased flexion loading on the spine. These findings may have some support from research conducted

by Dunk and Callaghan[31] who demonstrated that males displayed a more flexed lumbar spine and a more posteriorly tilted pelvis compared with females in normal sitting.

Sports that combine rotation with spine flexion and extension (eg. fast bowling in cricket) are known to carry greater risk for LBP[92]. Burnett et al[20] described rowing as one of a number of sports (eg. cricket, tennis, gymnastics) in which high levels of mechanical loading in association with coupled flexion/extension and axial rotation of the lumbar spine are undertaken together with medium to high levels of training and competition. This is supported by Adams and Dolan[3] who have shown that the addition of axial rotation along with flexion and moderate compressive forces can place considerably more stress upon passive stabilising structures such as capsule, ligaments and discs. It has been proposed that the risk of LBP is strongly influenced by the position of the lumbar spine and the nature of the load applied. There is an increased risk of tissue strain at end-range of spinal motion in which passive spinal structures are maximally loaded[89] and repeated end range flexion loading of the lumbar spine has been linked to LBP[107]. Prolonged ergometer rowing involves the spine "creeping" into end-range flexion therefore this factor may be a risk factor in on-water rowing[23].

In the general population and in sporting pursuits other than rowing, biomechanical risk factors for LBP include sustained posturing of the spine, particularly in prolonged sitting[11, 99], repeated end range loading[18, 32, 47, 118], combined movements of the trunk (eg. flexion and twisting)[92], and high volumes of load[119]. These factors are also evident in rowers as they spend many hours training and competing in a seated posture whilst the thoraco-lumbar spine is compressed, flexed and/or twisted.

Prolonged sitting has been previously associated with the presence of LBP[11, 103]. Sitting is known to generally cause a reduction in the lumbar lordosis[43, 64], however, the degree of lumbar curvature in seated postures may differ between individuals[18]. Callaghan and McGill[24] found that compressive forces acting on structures of the low back are increased when a prolonged sitting posture is adopted in comparison to a standing posture. This difference in joint loading was due to the increased flexed posture of the lumbar spine assumed when seated which results in increased passive tissue (ligament, posterior disc and facet joint) strain.

Gedalia et al[39] suggested that repetitive strain may also lead to de-sensitisation of the mechanoreceptors in spinal ligaments. These receptors often have pathways that lead to reflex activation of muscle. After repetitive motion, a reduction in protective muscle activity has been shown and this reduction is often seen for a number of hours after the exercise is completed. The ramification for rowers is that the athlete may be

more vulnerable to injury during this period, even when they may not be experiencing high loading of the spine.

High training and competition loads my also render the rower more prone to LBP[7]. Overuse injuries in sport are typically associated with activities that involve repetitive moderate to high mechanical load[18, 19] therefore, a simple strategy to implement is considering alternative methods of conditioning to better prepare the rower. Caldwell et al[23] suggest that this repetitive cyclic action of rowing may predispose the rower to lower back injury as in a single session a rower may train for 90 minutes during which time they may perform 1800 cycles of lumbar flexion. Lu et al[65] reported that the incidence of 'cumulative trauma disorder' may be evident in individuals who engage in repetitive or cyclic activity over a prolonged period, which may relate to the repetitive cyclic action in a rowing stroke. These authors suggest that high cyclic load magnitudes may elicit tissue strain indicative of acute inflammation in ligamentous, capsular or disc structures of the lumbar spine. Supporting this hypothesis is research by Solomonow et al[106] who reported that cyclic and repetitive sports have been shown to trigger high rates of musculoskeletal disorders when undertaken over long periods. In this study the authors demonstrated that prolonged cyclic loading may compromise spinal stability in the ensuing two to three hours after loading, thereby increasing the risk of spinal injury.

*1.3.1.2 **Physical Factors***

Physical factors are of interest with reference to the aetiology of LBP in sporting activities as it is how these factors interact with actual movement patterns that may provide an increased level of understanding to the aetiology of LBP in specific sports[42, 73]. Physical factors that are known to be associated with, or contribute to LBP, include deficits in back muscle endurance[83, 96], habitually adopting postures such as slump sitting[82], limitations in flexibility of the hamstrings[11, 37], deficits in motor control resulting in increased flexion strain[79] and joint hypermobility[38]. Deficits in spinal repositioning sense have also been reported to be associated with LBP[81]. Due to the cross-sectional nature of many of these studies it is not known whether the abovementioned deficits are as a result of LBP, or predispose individuals to back pain.

Previous studies have reported an association between LBP and a lack of back muscle endurance in industrial workers utilising repetitive flexion in their work[83] and deficits in back muscle endurance in individuals reporting LBP when compared with

healthy controls[96]. It could be speculated that poor back muscle endurance may render the spine vulnerable to increased tissue strain. Possible causes of reduced back muscle endurance might include disuse through inactivity[75], poor general conditioning, altered motor control patterns[84], or habitual positioning of the spine in postures associated with reduced activity of spinal stabilising muscles[86]. Recent research has also found a relationship between prolonged sitting and poor back muscle endurance[83].

O'Sullivan et al[82] reported a relationship between trunk muscle activity and different standing and sitting postures. The authors reported that lumbo-pelvic sitting posture (defined as anterior rotation of the pelvis, lumbar lordosis and relaxation of the thorax) results in tonic activity of the transversus portion of the internal oblique, superficial multifidus and in some cases thoracic erector spinae, suggesting that these muscles have a postural stabilising role. Activation of these muscles has been found to be reduced in slump sitting[82], where it is possible that load is placed on the passive spinal structures rather than the active stabilising muscles. This may have an effect on reducing back muscle endurance as reported by O'Sullivan and colleagues[83] who found evidence of a relationship between prolonged passive sitting postures and reduced back muscle endurance and LBP in subjects with flexion-provoked pain. As previously mentioned, evidence of back muscle fatigue during ergometer rowing was illustrated in a study by Caldwell et al[23] which has the potential to contribute to increased levels of lumbar flexion during the rowing stroke. Deficits in back muscle strength and endurance would enhance the effects of fatigue, given that competitive rowing is primarily a strength-endurance sport[7, 69]. Rowers staying at, or near end range for extended periods of time is something to avoid as there is increased risk of tissue strain at end range of spinal motion in which the passive spinal structures are maximally loaded[89].

Reduced lower limb muscle endurance has been previously identified as a physical characteristic existing prior to low back injury[113, 125]. Evidence of leg muscle fatigue contributing to a change in lifting posture, from semi-squat to stoop, during a repetitive lifting task[108, 117], was thought to occur as the former is less physiologically demanding[134]. This may be the result of fatigue in major lower limb muscles (quadriceps, gluteals and hamstrings) in semi-squat position. It may be hypothesised that this stoop posture, if habitually adopted due to poor endurance of the lower limb muscles, may be a factor contributing to increased end range flexion tissue loading on the lumbar spine during manuals tasks. High levels of lower limb muscle endurance in rowers may be of importance as the legs initiate and assist in the drive phase of the

rowing stroke[66] and it could be hypothesised that the rower's back is the main contributor to produce force on the oar should the rower's legs fatigue.

Reduced muscle flexibility around the pelvic girdle such as the hamstrings has been reported to be associated with LBP disorders in children[11]. It is thought that reduced hamstring and hip flexibility may result in increased flexion strain in the lower back during activities involving sitting and reaching movements such as rowing. Shortened hamstring muscles may limit the ability to achieve anterior rotation of the pelvis[37] and subsequently would result in the need to increase ranges of lumbar and thoracic flexion to reach for the catch in the rowing stroke[94]. Whilst reduced hamstring flexibility intuitively makes sense as a factor that may be related to LBP, a number of studies have failed to illustrate an association between hamstring flexibility and LBP. On this basis some authors have reported that techniques to increase hamstring flexibility may not prevent LBP or be useful in rehabilitation of LBP in rowers[49, 116]. Multiple factors may have an influence on the degree of lumbar flexion in rowing such as leg muscle endurance[52], back muscle endurance[96] and the length of time spent in a flexed posture during the drive phase of the stroke[79]. The effect of shortened hamstring muscles on the prevalence of LBP in rowers has not been clearly documented in the literature and may benefit from further investigation.

Limitations in anterior pelvic rotation have been identified as a technique fault in male and female rowers which may lead to increased flexion loading of the lumbar spine[70, 94]. In order to decrease forces on the lumbar spine it has been postulated that rowers should adopt a less flexed lumbar spine, particularly at the catch phase when the oar is placed in the water[23]. In this respect, if the pelvis could be rotated more anteriorly, less motion would be required in the lumbar spine[94]. A study by Gajdosik et al[37] showed that shorter hamstrings are associated with increases in range of lumbar and thoracic flexion in standing[37]. There may be an association between a greater degree of anterior rotation of the pelvis at the catch which has the potential to reduce the amount of lumbar flexion required, thereby reducing compressive load on the lumbar spine[23, 94].

Joint hypermobility as measured by the Beighton scale[30] has been previously reported as a risk factor for LBP in adolescent girls'[38]. It is considered that generalised joint laxity may reflect a deficit in the spine's passive stabilising structures to transmit loads effectively. On this basis, this is a factor that could be examined in a study examining female rowers.

Joint proprioception is fundamental to static and dynamic postural control[120]. In the spine, spinal muscles, spinal ligaments, facet joint capsules, intervertebral discs and

the thoracolumbar fascia all contain proprioceptive receptors[54, 120]. In mid-range neutral postures, in which ligaments and capsules are under minimal tension, proprioceptive receptors in spinal muscles are considered to be important to both movement and position sense[15, 16, 54]. Previous studies have demonstrated spine repositioning deficits in patients with LBP[15, 81, 122]. It is thought that these deficits may represent a fault in the spine's feedback control system rendering the spine at greater risk of tissue strain[15, 81]. Whether rowers with LBP have deficits in the spinal repositioning sense is not known.

1.3.2 Lifestyle Factors

Lifestyle factors might be important elements in the prevention of LBP, since they are modifiable in nature. Previous studies examining the association between LBP and smoking, alcohol consumption and obesity have been investigated in systematic reviews[56-58]. From these reviews there is evidence of positive associations between LBP and these lifestyle factors, however, possible causal links have not been established.

Whilst several studies have found an association between LBP and sitting in adolescence[8, 40], few studies have investigated the link between sitting and hours spent watching television and computer use. Balague and associates[10] in a field survey of 1755 children aged 8 – 16 years reported a correlation between the time spent watching television and increased risk for LBP and Troussier and associates[126] in a survey of 1178 children reported an increased risk for LBP in children who watched more than one hour of television per day. However, what is not clear is whether this association is linked purely to inactivity or other aspects of watching television. There have also been concerns regarding the specific physical stresses on children's bodies associated with computer use and the increase in back problems[114], however there is limited data on this relationship in the broader adolescent population.

The relationship between activity level and spinal pain remains contentious[133] and the relationship between physical activity and LBP may be non-linear. In fact it has been stated that a U-shaped relationship between physical activity and LBP may exist[25]. A review by Balague et al[8] concluded that competitive sports were associated with an increased risk of LBP. On the other hand, Salminen et al[100] reported that a low frequency of physical activity in the young might be a risk factor for LBP and that pursuing sports as a leisure time activity was not harmful and on the contrary had positive effects on spinal mobility and trunk muscle strength.

There is also debate regarding the influence of other forms of spinal loading such as the carriage of school bags. Grimmer and Williams[40] reported that LBP in adolescents was associated with the time spent carrying backpacks, however a prospective study[50] found that mechanical load such as carrying school bags was not associated with LBP in adolescence.

1.3.3 Psycho-social Factors

Psycho-social factors have been previously linked to the development and presence of adolescent back pain[93]. These factors may include psychological factors such as attitudes, beliefs (eg. beliefs about the consequences of LBP, fear avoidance), mood state (eg. anxiety and depression), and social factors. These factors interact with behaviour and combined are referred to as psycho-social factors[91].

Many psychological risk factors have been examined in the related literature in an attempt to determine predictors for LBP-related disability. Efforts to identify and modify risk factors may alter LBP-related outcomes. Cross-sectional, experimental and prospective studies have clearly shown that factors such as negative pain beliefs, fear of movement, anxiety and depression are related to LBP disability in both adults and children[62, 63, 67, 101]. Social factors including perceived level of support and socio-economic status are also associated with LBP disorders in adults[55, 59, 74] and children[44, 50, 53, 109]. Hence, there is strong evidence that beliefs, distress and illness behaviour are powerful contributors to LBP-related disability.

How patients think and feel about back pain is central to what they do about it and how it affects them[130]. Back pain beliefs are considered to be an important factor for LBP and its associated disability. Different aspects of beliefs exist with regards to LBP and these include the inevitable consequences of LBP[121] and fear avoidance beliefs[131]. Of particular concern is that back pain beliefs are considered of importance for the chronic LBP[17, 26]. As there has been no study addressing back pain beliefs in adolescents this is a factor worthy of investigation.

Pain is commonly accompanied by emotional arousal and distress[93]. Distress may raise awareness of bodily sensations, increase the severity of pain, and lower pain tolerance[130]. Moreover, it is known that psychological distress has the capacity to alter motor control parameters across the spine as well as lower pain thresholds[61] and it makes us more concerned about the pain and more likely to seek professional care. The most commonly identified aspects of psychological distress are depression and anxiety,

associated both within the workplace environment and/or individual social situation and there is some evidence that high levels of psychological distress are predictive of future LBP episodes[34]. Watson et al[132] in a cross-sectional study of 1446 schoolchildren suggested that psycho-social factors rather than mechanical factors were more important in LBP occurring in young populations and could possibly be a reflection of distress in schoolchildren.

There is evidence that people of lower social status have increased levels of disability related to their LBP[55, 74, 130]. Social class covers a host of social, educational, occupational, economic, lifestyle, and psycho-social factors, and corresponding social and health attitudes and behaviour[130]. Any or all of these might influence disability associated with back pain, however causal relationships have not been established.

Previous studies have strong associations between the regular practice of sports and psychological wellbeing[51, 87]. Therefore, the presence of psycho-social risk factors and the relationship to the incidence of LBP amongst schoolgirl rowers warrants investigation. It may be that the promotion of physical fitness and performance whilst participating in a team with peers, and creating an environment in which rowers get individual attention, feedback and support from those who are attentive to psycho-social markers and the possible contribution to LBP, is of benefit. New directions in primary care focus on patients' worries and perceptions about the origin of the pain and the beliefs about the efficacy of treatments offered[91]. Hence, educating athletes such as rowers on caring for themselves and preparing the bodies for the sport may play an important role in decreasing the incidence of LBP.

Key Points

- LBP is a complex musculoskeletal disorder and has been previously examined within a bio-psycho-social framework.
- As the aetiology of LBP is multi-factorial this should be reflected when examining LBP in rowing.
- Little is known about the possible etiological factors of LBP in adolescent female rowers.

1.4 PREVENTION OF FIRST EPISODE AND RECURRENCE OF LBP

Participating in competitive sport without injury is an important goal for athletes to be able to improve the level of performance. Unfortunately, keeping athletes injury-free in rowing is a difficult task for rowing coaches. It is believed there is limited scope in preventing the first episode of LBP in the general population[22], however few studies have examined the efficacy of exercise interventions in preventing first-episode or recurrent LBP in sporting populations. In the few studies that have been conducted, two distinct approaches have been used they being; "core strengthening"[27, 77] and undertaking so-called "specific exercise". Regardless of the approach used, the documented exercise interventions to decrease the incidence of LBP in sporting populations largely have been generic exercise programs delivered in group settings with limited efficacy[27, 41, 77, 127].

1.4.1 Intervention Studies to Decrease LBP in Sport

1.4.1.1 Core Strengthening

Strengthening the body's core is an approach that is widely used and is believed to improve performance[72, 112, 127] and prevent spinal injuries[5, 27, 77] and it has also become a major trend in exercise rehabilitation[5]. The term "core strengthening" has been used as a collective term to embrace concepts such as lumbar stabilisation, motor control training and other exercise regimens. However, regardless of the terminology used, core strengthening is a description of the muscular control required around the spine to maintain functional stability[5]. However, exercise of the core musculature is believed to be more than just trunk strengthening[5]. In a review of core strengthening by Akuthota and Nadler[5] the authors stated that motor re-learning of inhibited muscles may be more important than strengthening in patients with LBP and that exercise must be progressed from training isolated muscles to training as an integrated unit to facilitate functional activity. However a recent review paper questions the whole validity of the core stabilisation concept[60].

LBP intervention studies have typically utilised generic programs (ie. a one program fits all approach) and these studies have had mixed outcomes. In the review of Akuthota and Nadler[5] it was suggested that the initial core strengthening protocol should enable people to become aware of motor patterns. Some individuals will need to learn to recruit muscles in isolation or with motor patterns. When the trained muscle is 'awakened' in isolation exercises, training should shift to functional positions, and then

progressed accordingly. Stabilisation exercises can be progressed from a beginner level to a more advanced level and these may include exercises such as the curl up, the side bridge, and the bird and dog exercise. As rowing involves movement in all three planes, core musculature must be addressed and trained in these planes. In addition, a problem with this approach is that anecdotal evidence from experienced clinicians reveals that some people with back pain may have over active muscles and cannot relax.

There have been three studies that have examined *core strengthening* as a method to prevent/treat LBP in sport and there has been one study that has utilised *core strengthening* to improve performance in rowers. These studies are detailed below.

Cusi and associates[27] examined the effects of a randomly assigned back strength Swiss ball exercise intervention to prevent back and groin injuries in two groups of age, height, weight and position-matched rugby players. Measurements of flexibility and back strength were taken pre-, mid- and end-season, and back and groin injuries were surveyed throughout the season. Subjects were randomly assigned to an intervention group and both intervention and control groups carried out a 10-week standard stretching and fitness regime. The intervention group also carried out three additional exercises on a Swiss ball twice weekly throughout the season. There were significant improvements in both flexibility and strength in both groups. The intervention group demonstrated fewer relevant injuries. The intervention group had a greater range of improvement in strength and flexibility but the differences did not achieve statistical significance.

Nadler et al[77] investigated the influence of a 30–45 minute core strengthening program performed four to five times per week pre-season and two to three times per week during the season on LBP recurrence and hip strength differences in collegiate athletes. Measurements of hip strength were taken over consecutive years in the same group of athletes and occurrence of LBP was monitored throughout the year. The strengthening program was undertaken during the second year of the study and strength differences were measured. The results of this investigation did not demonstrate any significant difference in LBP incidence after completion of a core strengthening program instituted by a certified strength and conditioning coach which involved strengthening of the abdominals, paraspinal and hip extensor muscles, though this may be a reflection of the small number who actually required treatment.

In a group of college rowers, Tse et al[127] investigated the effectiveness of an eight week intervention program aimed at improving the core endurance of the trunk muscles and performance on various functional performance tasks. Trunk endurance

was assessed using flexion (abdominal fatigue test), extension (back extension test) and side flexion tests (side flexion bridge test), and a variety of functional performance measures were assessed (vertical jump, broad jump, shuttle run, 40m sprint, overhead medicine ball throw, 2000m maximal ergometer test). The results demonstrated that the male rowers who undertook the program that targeted the transversus abdominis and multifidus muscles improved selected core endurance parameters (right and left side bridge test), but the effectiveness of the core intervention on various functional performance aspects was not supported. Of interest, the authors' claimed that improvements in core endurance may be influential in preventing and reducing episodes of LBP despite no data being collected to support this suggestion.

1.4.1.2 Specific Exercise

Other researchers have used *specific exercise* regimes to address potential deficits that are applicable to the athlete's chosen sport. The latter term has been given because these exercise regimens are implemented to address the specific needs of the sport and physical deficits of the athletes[41, 52]. Specific muscle control exercises targeting co-contraction of the transversus abdominis and multifidus muscles in patients with low back pain, have shown reduced pain intensity and functional disability levels in some studies[84, 95] but not in others[33]. However, there are limited studies demonstrating the efficacy of specific exercise interventions for the prevention of LBP in athletic populations or adolescent populations. Examples of specific exercise interventions are outlined below.

Harringe et al[41] evaluated specific segmental muscle control exercises directed at the transversus abdominis and multifidus muscles of the lumbar spine in 51 young female gymnasts (aged 11-16 years) with and without LBP, in a controlled group setting. The experimental group who undertook a 12-week specific segmental muscle training program based on the drawing-in action called abdominal hollowing. This is an isometric co-contraction of the transversus abdominis and the lumbar multifidus muscles. The experimental group demonstrated a significant reduction of days with LBP and reduced pain intensity compared with gymnasts in the control group. However, there were a number of methodological limitations of this study which included non-randomisation of subjects and differences in anthropometric data between the groups which limits the validity of the findings. In this investigation the exercises were not individualised to the athlete.

Koutedakis et al[52] investigated the effects of a specific hamstring strengthening program using predominantly free weights, in reducing the prevalence of LBP in female rowers. The authors reported that a six to eight month strengthening program could reduce LBP incidence. The strength training program specifically for the hamstrings was undertaken in one sub-group of female rowers, with strength testing performed pre-training and post- training six to eight months later. As there was no control group for the comparison in this study it is important to consider that improvements in hamstring strength may also have been demonstrated as a result of conditioning associated with rowing training. This is an area which clearly requires further investigation.

1.4.2 Sub-classification of LBP

Recent trends in the physiotherapy management of chronic spinal pain disorders have focused on the application of specific motor control interventions to retrain spinal motor control[84, 115]. The design of examination-based specific exercise programs address the specific motor dysfunction of each subject in a functional manner, while taking into account the pain behaviour, cognitive aspects of the disorder and individual functional impairments[85]. This management approach requires a high degree of skill and expertise on the part of the treating physiotherapist, to initially train the motor control patterns and then to integrate this new motor skill into the previously painful postures and activities which were part of the patient's normal lifestyle. To date no injury preventions programs for rowers have been documented that have included individualised specific exercise programs to address specific motor dysfunctions and it is worthy of investigation in schoolgirl rowers.

A method of classification of non-specific chronic LBP has been developed by O'Sullivan[29, 80, 85] whereby patients' with localised mechanically provoked LBP are sub-grouped based on the pain behaviour and impairments in the spinal motor control[80]. Five sub-groups of non-specific chronic LBP patients have been reliably identified by musculoskeletal physiotherapists[29, 129]. Of these groups it is the 'flexion' pattern disorder that may be of the most concern to adolescent female rowers as this sub-group experiences pain in relation to impairments of control in flexion-related postures and functional activities (forward bending, cycling). The flexion pattern is defined as motor control impairment of the lumbar spine with a tendency to flexion strain (loss of segmental lordosis) at the symptomatic spinal region. Flexion pain disorders are associated with functional loss of motor control into flexion resulting in an excessive

abnormal flexion strain[29]. The classification process involves a comprehensive subjective and physical examination to identify the motor control impairment pattern based on the clinical presentation. Classification of rowers with LBP may relate to proprioceptive deficits and warrants investigation in this group of schoolgirl rowers.

With the advent of positive findings on tailored treatment for sub-classified LBP patients'[14, 36, 84, 115], when compared with generic treatment approaches on a heterogeneous LBP population, individualised specific exercise in combination with other intervention approaches such as pre-season conditioning, cross-training and back education may hold promise to reduce pain and disability related to LBP in schoolgirl rowers. Multi-dimensional interventions have been recommended as a suitable strategy to consider to address LBP in adolescence, due to the complex multi-factorial nature of LBP in sport[1]. A recent systematic review by Abernethy and Bleakley[1] examining the effectiveness of preventative interventions in adolescent sport concluded that multi-faceted interventions that consider pre-season conditioning, functional training, education, proprioceptive balance training and sport specific skills which are continued throughout the season are warranted. However, to date the efficacy of this approach has not been investigated.

Recent trends in the physiotherapy management of chronic spinal pain disorders have focused on the application of specific motor control interventions to retrain postural and segmental stabilising muscles which become dysfunctional[84, 115]. Further, retraining of habitual postures (sitting and standing) in which pain is provoked by end range strain[88] is of importance. The idea of improved outcomes in individualised specific exercise intervention has received support in other pain disorders. For example, Stuge and associates[115] in a study evaluating the efficacy of a treatment program focusing on specific stabilising exercise for pelvic girdle pain after pregnancy found an individualised treatment approach to be more effective than generic physical therapy. Similar outcomes were also found by Fritz and associates[36], who concluded that for patients with acute, work-related LBP, the use of a classification-based approach in which patients are matched with specific intervention or treatments resulted in improved disability and return to work status after four weeks when compared with therapy based on clinical guidelines.

The primary focus of management in specific individual exercise intervention is to correct postures and movement patterns that are linked to maintaining the pain disorder within a cognitive framework. This approach is based on a motor control model whereby the faulty movement pattern or patterns are identified, the components

of the movement are isolated and retrained into functional tasks specific to the patients needs[84]. This approach to management is different to conditioning approaches to exercise, in which the primary focus is on the recruitment of motor units, as in the motor learning approach to exercise training focuses more on the quality and control of spinal posture and movement. This frequently involves inhibiting dominant muscle activity. This is based on the identification of specific motor control deficits in the movements and postures that these muscles control[80].

The effects of an individually applied specific physiotherapy exercise intervention in conjunction with education and pre- and through- season conditioning on the prevalence of LBP and changes in pain intensity and disability levels with athletes who experience LBP in sporting populations has not been well documented and this is an area that warrants further research.

Key Points

- There is a significant lack of effective interventions reported in the literature that address modifiable factors that are considered to be associated with, or cause LBP in rowers.
- "Core strengthening" and "specific exercise" are two approaches that have been adopted to reduce the incidence of LBP.
- There is no study that has yet sub-classified LBP in rowers.
- To date, no study has applied a motor control intervention to rowers for the prevention of LBP.
- Whilst these uni-dimensional approaches to injury prevention have been investigated in some sporting populations, a multi-dimensional approach should be considered due to the complex and multi-factorial nature of LBP.

1.5 OBJECTIVES AND SPECIFIC AIMS OF THE THESIS

This doctoral investigation examined various aspects of LBP in schoolgirl rowers and consisted of three related studies. The thesis had three broad objectives and these were specific to each study as outlined in Figure 1.3. Study I first sought to determine the extent and nature of the LBP problem in schoolgirl rowers. Factors from the bio-psycho-social domain that were considered to be of importance to LBP in schoolgirl rowers were then examined in Study II. Based on these findings, Study III then examined whether a multi-dimensional intervention program was capable of

decreasing the incidence of LBP and the associated levels of disability in schoolgirl rowers. The design of this thesis followed the approach of van Mechelen's model of sports injury prevention which has been proven as a valuable tool to guide injury research[128]. This four stage approach aims to: 1) establish the extent of the problem; 2) establish the aetiology and mechanisms for injury; 3) introduce preventative measures; and 4) assess their effectiveness. The thesis design also supports the principles of Meeuwisse[71] who proposed a multi-factorial model for assessing injury prevention and Finch[35], whose six stage approach includes the necessity of implementation research to ensure that prevention methods are adopted.

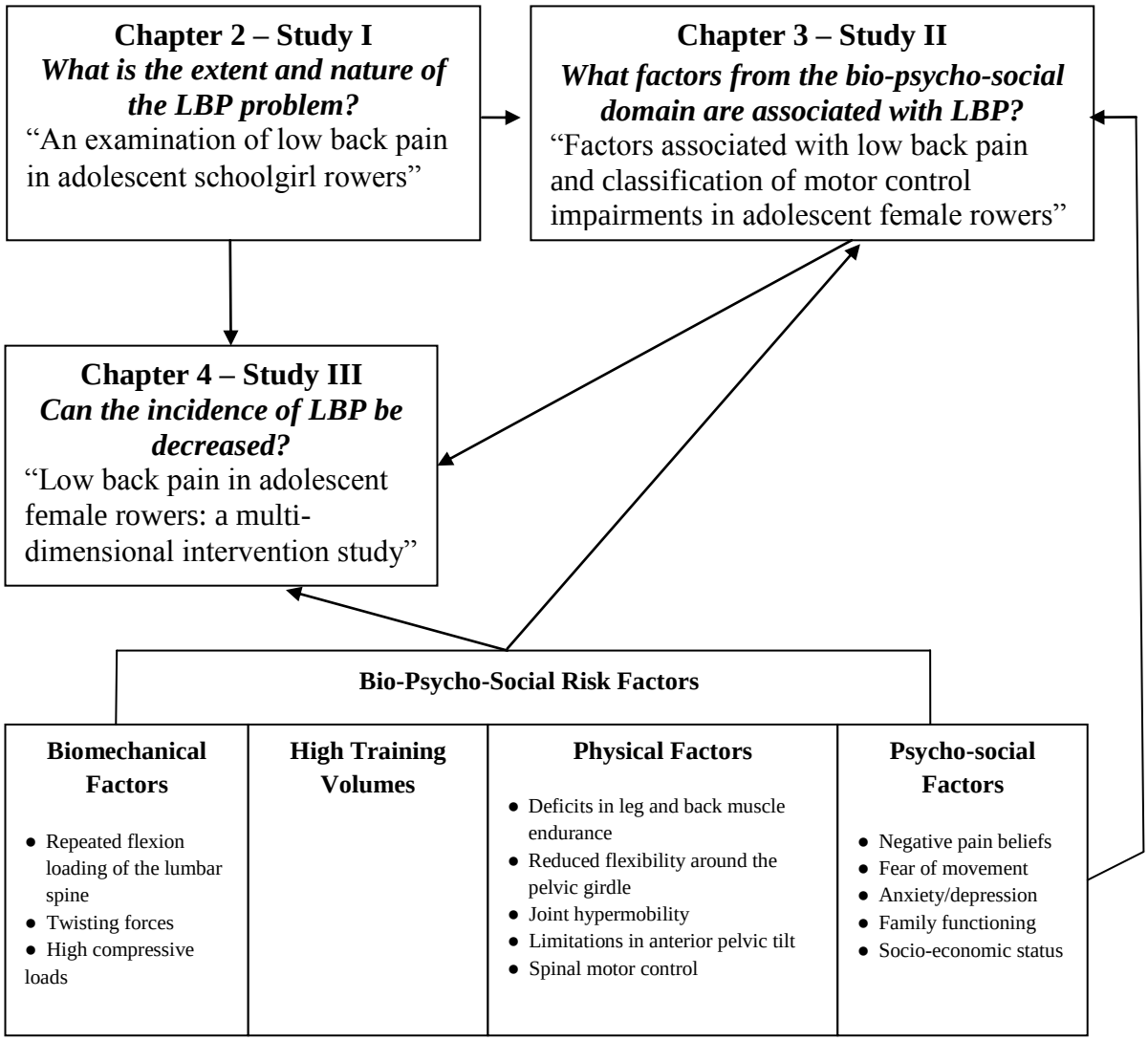

Figure 1.3 A schematic representation outlining the objectives of the thesis and how the studies in the thesis were related.

The specific aims of the Studies I-III were as follows:

Chapter 2 – Study I. "An examination of low back pain in adolescent schoolgirl rowers".

- Determine the point prevalence of LBP in schoolgirl rowers and compare this figure to a matched non-rowing control group.
- Examine the factors that reflect the initial onset of LBP, or exacerbate pre-existing LBP in schoolgirl rowers.

Chapter 3 – Study II. "Factors associated with low back pain and classification of motor control impairments in adolescent female rowers".

- Investigate differences in physical and psycho-social factors in schoolgirl rowers with and without LBP.
- To describe the patterns of motor control impairment present in those with LBP.

Chapter 4 – Study III. "Low Back Pain in Adolescent Female Rowers: A Multi-dimensional Intervention Study".

- Examine whether a multi-dimensional intervention program can decrease the incidence of LBP and the associated levels of pain and disability in schoolgirl rowers.
- Examine the changes in secondary variables within a bio-psycho-social framework in a group of schoolgirl rowers participating in a multi-dimensional intervention program.

1.6 LIMITATIONS OF THE THESIS

There are general limitations to this thesis that need to be stated. Firstly, mechanical loading factors related to rowing were not examined in this doctoral investigation. Secondly, whilst LBP outcome measures (incidence, level of pain and disability) were examined in this thesis quantifiable rowing performance-related measures (eg. 2000m rowing ergometer test) were not assessed. Thirdly. a cross-sectional design was utilised in Study II therefore, the issue of cause and effect cannot be resolved. Fourthly, whilst this thesis was predominantly conducted in the field, (therefore it has high ecological validity) in some instances strict experimental control

was not possible. For example, Study III of this thesis was a non-randomised control trial which provides a lower level of evidence when compared with a true randomised controlled trial. Randomising a sample as such is logistically difficult in a school/sporting situation. Fifthly, a multi-dimensional intervention approach was adopted in Study III as recommended in previous peer-reviewed literature[6]. Whilst taking into account many factors in the intervention, the exact mechanism to identify the decrease in LBP prevalence cannot be identified. Finally, this doctoral investigation examined schoolgirl rowers who attended schools of high socio-economic status therefore, the results cannot be generalised to schoolboys, those from lower socio-economic backgrounds and older higher-ability rowers.

1.7 SIGNIFICANCE OF THE THESIS

Rowing is one of the largest participant sports within the Independent Girls' Schools Sporting Association (IGSSA) in Western Australia with approximately 400 participants every year. Rowing is a sport offered to girls 14 years of age and above, with these girls competing and training in both sweep and scull boats. Each season there are five interschool regattas over the winter months (May – August), culminating with the prestigious Head of the River regatta. Training generally commences in most schools in March at the conclusion of the interschool Swimming season, however, some schools continue to train over the summer months. Victory in the Head of the River regatta receives significant media coverage, and there is fierce competition and rivalry between schools.

In 1999, a decision was made to replace sweep fours with quadruple sculls by the association. This direction was introduced as it was considered that the increased twisting action of sweep oar rowing may contribute to a higher incidence of LBP. However, IGSSA still allows schoolgirl rowers to compete in sweep eight at all age levels. IGSSA recognised that research was required to investigate LBP in this population. This study, to the best of my knowledge, is the first to examine LBP within a bio-psycho-social model in a sporting population.

This research is clearly of practical significance and has implications for the way that injury prevention and rehabilitation programs are conducted in schools and other sporting programs. Further, this thesis has the potential to inform on safe training practices, screening and selection methods to minimise the occurrence of LBP in

schoolgirl rowers. Such data is also important for the Principals' of the IGSSA Schools in Western Australia to assist them in formulating policy based upon experimentally determined evidence.

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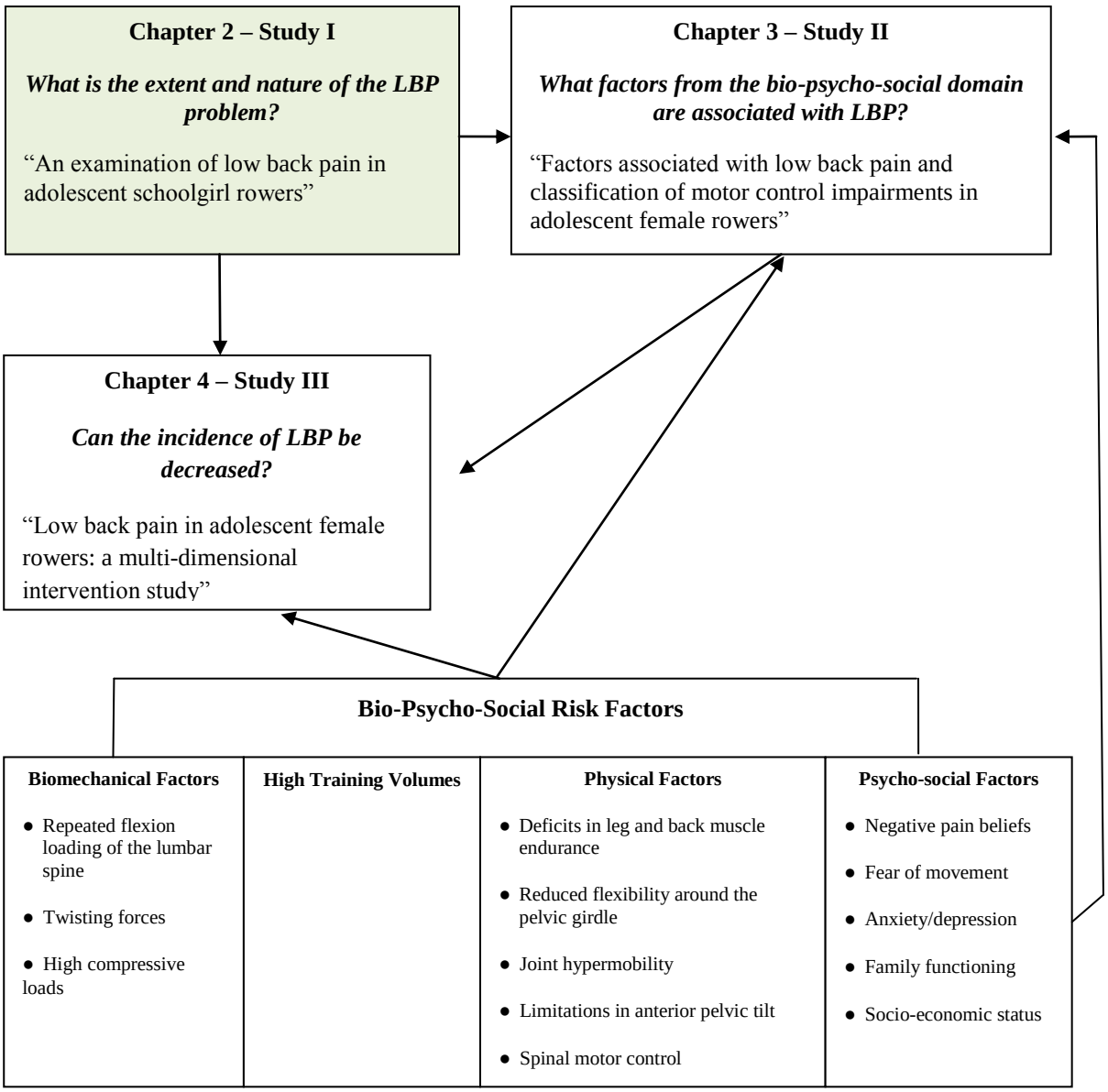
CHAPTER 2 – STUDY I

"An examination of low back pain in adolescent schoolgirl rowers"

Clinical evidence suggests that low back pain (LBP) is common in rowers. Adolescents who suffer from LBP are at increased risk of recurrent and chronic LBP during adulthood. Therefore, this period is a critical period to investigate the development of LBP. The first study of this thesis was conducted amongst the Schoolgirl rowing population in Western Australia to determine the extent and nature of the LBP problem.

The general aims of the study were to determine the point prevalence of LBP in schoolgirl rowers and compare this figure to a matched non-rowing control group, and to examine the factors that reflect the initial onset of LBP, or exacerbate pre-existing LBP in schoolgirl rowers.


Chapter 2 – Study I
What is the extent and nature of the LBP problem?
"An examination of low back pain in adolescent schoolgirl rowers"
Chapter 3 – Study II
What factors from the bio-psycho-social domain are associated with LBP?
"Factors associated with low back pain and classification of motor control impairments in adolescent female rowers"
Chapter 4 – Study III
Can the incidence of LBP be decreased?
"Low back pain in adolescent female rowers: a multi-dimensional intervention study"
Bio-Psycho-Social Risk Factors
Biomechanical Factors
Repeated flexion loading of the lumbar spine
Twisting forces
High compressive loads
High Training Volumes
Physical Factors
Deficits in leg and back muscle endurance
Reduced flexibility around the pelvic girdle
Joint hypermobility
Limitations in anterior pelvic tilt
Spinal motor control
Psycho-social Factors
Negative pain beliefs
Fear of movement
Anxiety/depression
Family functioning
Socio-economic status

This chapter is presented in the pre-publication format of the following article:
Perich D, Burnett A, O'Sullivan P. An examination of low back pain in adolescent schoolgirl rowers. *Submitted.*

2.1 ABSTRACT

This cross-sectional study was undertaken to determine the incidence of low back pain (LBP) in schoolgirl rowers and to examine the self-reported factors that are associated with the initial onset of LBP, or exacerbate pre-existing LBP. Participants included 356 schoolgirl rowers and 496 age-matched non-rowers from schools involved in the schoolgirl rowing competition in Western Australia. Incidence of LBP and the levels of LBP and LBP-related disability for rowers and non-rowers were measured in addition to self-reported factors that bring on (or exacerbate) LBP, training hours completed per week and boats most frequently rowed in for rowers only.

Significant differences were evident in pain incidence between rowers and non-rowers for all ages examined in this study. Further, there was a significant difference evident for pain incidence between Year 9 and 10 rowers. Rowers showed significantly greater pain and disability scores when compared with non-rowers. A number of self-reported rowing-related and habitual factors were associated with LBP in rowers.

The results of this study indicate that LBP is common in schoolgirl rowers and there are several exacerbating factors that bring on or exacerbate LBP. Other factors that contribute to LBP in this group warrant further investigation.

2.2 INTRODUCTION

Rowing is a sport that is known to have several musculoskeletal problems associated with it[34] and there is evidence to suggest low back pain (LBP) is common in collegiate[33, 42] and senior rowers[9, 23, 25, 39, 44]. Rowing is one of the largest participant sports of the Independent Girls' Schools (IGSSA) sporting calendar in Western Australia with over 400 participants each year and anecdotal reports have stated that LBP is common in this group.

In the general LBP literature, the prevalence of LBP is known to be higher in females and also increases through adolescence[7]. It is unknown whether LBP incidence increases with age in adolescent schoolgirl rowers. Further, it is unknown whether physical factors play an important role in LBP in this group.

The purpose of the present study was to determine the incidence and exacerbating factors of LBP and what self-reported physical factors are associated with it in the IGSSA rowing program in Western Australia. Data from such a study may assist in determining the extent of this problem and may assist the formulation of future policy to ensure the safe participation of these rowers.

2.3 MATERIALS AND METHODS

2.3.1 Participants

Participants in this study included 356 schoolgirl rowers who were enrolled in a school-based rowing program in 2005 and 496 age-matched non-rowing schoolgirls who acted as a control group. The cohort of rowers examined in this study comprised 72% of the total number of rowers in the IGSSA competition. Participants were between the ages of 14-17 years and were recruited from all schools in the competition and hence were of similar socioeconomic background. Australian government statistics show that these schools had socio-economic status (SES) scores ranging between 110 and 125 in the SES funding model which links student residential addresses to national census data[3]. These scores were well above the average SES score of 98.8 for schools in Western Australia[4].

Participants completed a questionnaire midway through the competitive rowing season (approximately 3-5 weeks into the season and approximately 8-10 weeks after commencement of training) to determine firstly, the prevalence of LBP and secondly, to examine self-reported factors that either bring-on first episode LBP or exacerbate

existing LBP. Permission to conduct the study was granted by the Institutional Human Research Ethics committee (Appendix A).

2.3.2 Measures and Procedures

To assess the incidence of LBP, all participants completed a brief questionnaire (Appendix B and C) regarding the LBP history. Rowers were asked whether they were currently experiencing LBP whilst rowing or other activities and non-rowers indicated whether they were currently experiencing LBP whilst playing sport. Rowers were asked in which boats they predominately trained. Rowers in this study were also asked about the average number of training hours per week that they dedicated to rowing and other school-based sports. They also provided the number of hours per week they participated in sport outside of school sport (options were 0 hours, <5 hours or >5 hours).

Both rowers and non-rowers who experienced LBP at the time of testing completed a 10cm visual analogue scale (VAS) to assess the usual level of pain in the week prior to data collection[31]. A score of greater than 3 out of 10 on the VAS was considered to represent a moderate pain level[17]. All participants also completed the revised Oswestry Disability Questionnaire (Appendix D) to assess the level of LBP-related disability[26] and a score of greater than 12% for the disability score was considered to be clinically significant.

Rowers with LBP were also asked whether any of; lifting a rowing shell, rowing in a sweep boat, rowing in a quadruple scull, rowing in a single scull, ergometer rowing or long rows in a training session brought on, or exacerbated the LBP. They were also given the opportunity to add other activities that exacerbated the LBP.

2.3.3 Statistical Analysis

Data for 16 and 17 year old schoolgirl rowers were merged as these age groups compete in the one category (Seniors) and the fact that there was a marked reduction in the number of 17 year olds participating due to the importance of University entrance exams. To determine whether the incidence of LBP differed between-groups (rowers and non-rowers) and between-years χ^2 statistics were used. Independent t-tests were used to determine whether subject characteristics (age, height and weight) and the level of LBP and LBP-related disability differed between rowers and non-rowers. Descriptive

statistics were calculated for all other data. An alpha level of 0.05 was used for statistical analysis using SPSSV16 for Windows (SPSS Inc., Chicago: USA).

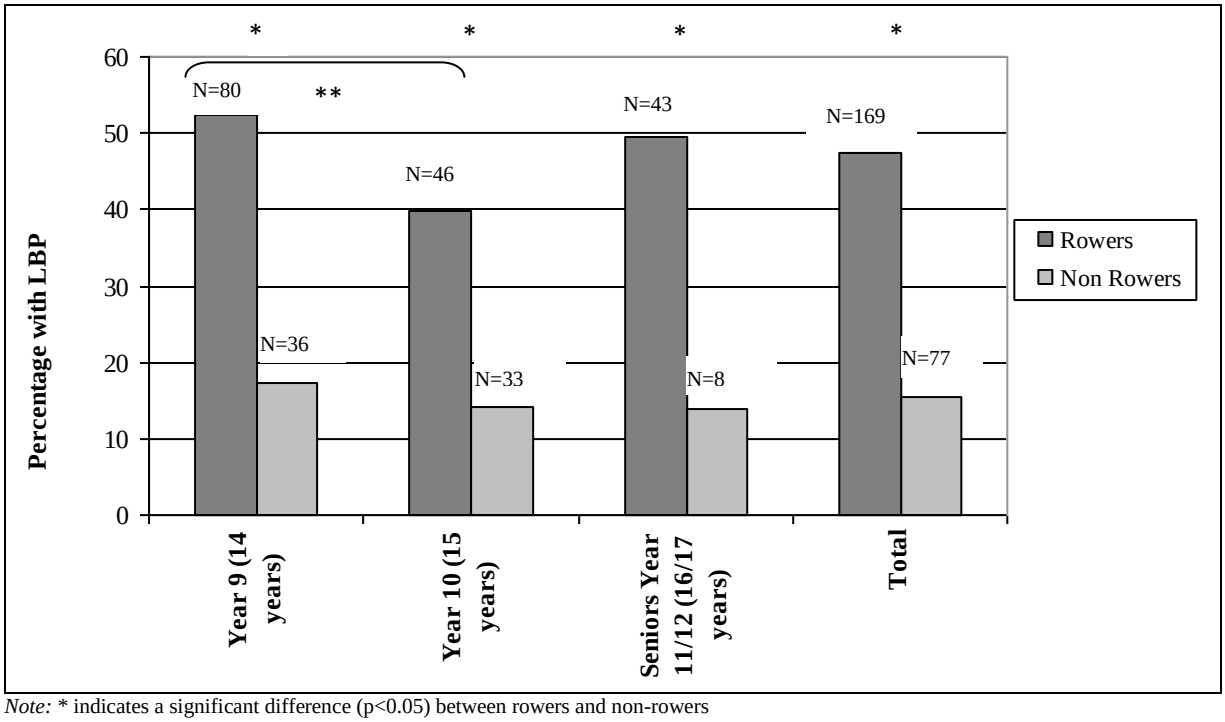
2.4 RESULTS

Subject characteristics and the LBP-related outcome measures (pain and disability) for rowers and non-rowers are provided in Table 2.1. The point prevalence of LBP for rowers and non-rowers was 47.5% and 15.5% respectively (Figure 2.1) and χ^2 analyses revealed that significant differences ($p<0.001$) existed between rowers and non-rowers of all ages. Further, a significant difference existed in LBP incidence between Year 9 and Year 10 rowers ($\chi^2 = 4.228$, $p=0.048$). It was interesting to note that 23.3% of the rowers without LBP indicated that they had previously experienced LBP, as did 34.5% of non-rowers.

Table 2.1: Characteristics of rowers and non-rowers at data collection (mean±SD).

		Rowers	Non-Rowers	p-value
Year 9	Age (years)	14.2 (0.3)	14.3 (0.3)	0.003 *
	Height (cm)	165.3 (11.3)	166.5 (22.8)	0.820
	Weight (kg)	54.8 (9.3)	53.8 (8.4)	0.338
	Pain (/10)	4.8 (2.0)	3.5 (2.2)	<0.001 *
	Disability (%)	10.3 (8.9)	9.8 (10.8)	0.793
	N	153	207	
Year 10	Age (years)	15.2 (0.3)	15.3 (0.3)	0.181
	Height (cm)	169.7 (7.0)	166.1 (7.2)	<0.001 *
	Weight (kg)	58.2 (8.7)	55.5 (10.9)	0.028 *
	Pain (/10)	5.1 (1.7)	3.4 (1.9)	<0.001 *
	Disability (%)	12.7 (8.9)	7.7 (6.7)	0.002 *
	N	116	232	
Seniors	Age (years)	16.7 (0.6)	16.2 (0.3)	<0.001 *
	Height (cm)	170.5 (6.2)	167.7 (7.1)	0.014 *
	Weight (kg)	61.6 (9.1)	58.4 (6.4)	0.027 *
	Pain (/10)	5.1 (1.9)	3.6 (2.4)	0.013 *
	Disability (%)	12.3 (9.5)	9.3 (6.2)	0.199
	N	87	57	
Pooled subjects	Age (years)	15.1 (1.1)	15.0 (0.7)	0.010 *
	Height (cm)	168.3 (7.2)	166.5 (15.8)	0.048 *
	Weight (kg)	57.5 (9.4)	55.2 (9.5)	<0.001*
	Pain (/10)	5.0 (1.9)	3.4 (2.1)	<0.001 *
	Disability (%)	11.4 (9.1)	8.8 (8.6)	0.012 *
	N	356	496	

Note: * indicates a significant difference ($p<0.05$) between rowers and non-rowers



Note: * indicates a significant difference ($p<0.05$) between rowers and non-rowers

Note: ** indicates a significant difference ($p<0.05$) between the rowers in the age groups included in the bracket.

Figure 2.1: Percentage of subjects experiencing low back pain (LBP) when considered by rowing status (rowers, non-rowers) and by age group (Year 9, Year 10 and Year 11/12). Absolute numbers of subjects with LBP in each group are listed above the columns.

Rowers reporting LBP, when all ages were pooled, showed significantly greater levels of pain and disability than non-rowers with 102 (60.4%) rowers reported moderate pain levels and 48 (28.4%) rowers reported clinically significant disability scores.

Rowers reported multiple factors that provoked or exacerbated the LBP (Table 2.2). Long rows in training sessions, lifting the rowing shell and rowing in a sweep eight were reported most commonly. Other exacerbating factors reported by rowers were lifting dinghies, racing and participating in weight training sessions. The most common reasons for LBP affecting everyday function for rowers were lifting, sitting and standing.

Rowers were asked which boats they predominantly trained in. Although there were some rowers, particularly in the younger age group who reported that they generally trained in a quadruple scull, most rowers reported that the majority of the training was completed in a sweep eight boat (Table 2.3).

Table 2.2: Factors reported to bring on or exacerbate LBP

Lifting a rowing shell	Sweep rowing in an eight	Rowing in a quadruples scull	Rowing in a single scull	Ergometer Rowing	Long rows in a training session	Coxing
86 (69.9%)	79 (64.2%)	45 (36.6%)	17 (13.8%)	60 (48.8%)	97 (78.9%)	17 (13.8%)

Whole numbers represent the number of participants who reported as a factor of bringing on or exacerbating LBP

Table 2.3: Description of boats in which rowers most frequently trained

Year 9 – 14 Years			Year 10 – 15 Years			Seniors (16/17 Years)		
Sweep	Quad Scull	Single Scull	Sweep	Quad Scull	Single Scull	Sweep	Quad Scull	Single Scull
63 (41.2%)	89 (58.2%)	1 (0.7%)	96 (82.8%)	16 (13.8%)	4 (3.4%)	76 (87.4%)	10 (11.5%)	1 (1.1%)

Whole numbers represent the number of participants who reported the boat in which the rower most frequently trained

Rowing-related training hours were shown to increase with age. The average number of training hours per week were 6.7, 7.7 and 9.2 hours for the 14 year olds, 15 year olds and seniors (pooled group of 16 and 17 year olds), respectively. Training hours on land (including ergometer training) were 1.1, 1.5 and 2.0 hours per week for 14 year olds, 15 year olds and seniors respectively. In addition, 65.7% of rowers indicated that they spent less than 5 hours per week with other sporting interests.

2.5 DISCUSSION

The aims of this study were to investigate the incidence of LBP amongst schoolgirl rowers and to determine the associated pain and disability levels. Self-reported factors that were associated with LBP in this population were also reported.

An important finding of this study was that the anecdotal reports of the high incidence of LBP in this group of schoolgirl rowers were confirmed. When examining the levels of LBP and LBP-related disability in these rowers, 60% of those with pain reported moderate pain levels whilst 28% reported clinically significant levels of LBP-related disability. These data are of particular concern as LBP in adolescence is considered a risk factor for LBP in late adolescence and adulthood[14].

Whilst levels of physical activity weren't quantified via a validated questionnaire (eg. International Physical Activity Questionnaire)[10] or direct qualitative assessment (eg. accelerometers or pedometers)[19, 21, 29], the non-rowers examined in this study were known to undertake high levels of physical activity through the IGSSA sporting calendar. Specifically, they participated in sports such as netball, hockey, basketball and cross-country so it can be assumed they acted as a physical activity-matched control group. Therefore, it is suspected that it is the actual activity of rowing rather than the overall volume of general physical activity that brings on and/or exacerbates LBP. In the general population, biomechanical risk factors for LBP include sustained posturing of the spine, particularly in prolonged sitting[6, 35], repeated end range loading[11, 18, 24, 40], combined movements of the trunk (eg activities that combine rotation with spine flexion or extension) and high training volumes and loads[41]. As rowers spend many hours training and competing in a seated posture whilst the thoracolumbar spine is near end-range flexion [30] and in a twisted position (in the case of sweep rowing), these factors may contribute to the prevalence of LBP in schoolgirl rowers. Long rows in a training session were also reported as the most prevalent factor that brought on or exacerbated LBP in this study and the related "pain ramping" effect has been shown in previous research that has used a rowing ergometer model[30].

It has been previously reported that there is a progressive increase in LBP incidence with an increase in age through adolescence[7, 22, 36, 37] however, an interesting finding of this study was that 14 year old (Year 9) rowers had higher pain incidence than 15 year old (Year 10) rowers. This may have been due to the fact that in the IGSSA competition, rowers are first exposed to the sport of rowing in Year 9 hence, coaches accelerate the student's learning by spending time with this group on-water to teach them the basic technical skills of rowing, Therefore, they are exposed to a physically demanding sport (as explained above) without the background exposure or the physical preparedness to handle this specific type of load. This is a similar problem to that experienced in other sports in which adolescents have a high incidence of LBP[12]. A sudden increase in specific mechanical loading applied to the athlete's body when commencing rowing training may not be conducive with good back health and care should be taken to introduce training and competition load gradually. A multi-dimensional approach to prepare the rower's body for this increased load may be required to address this issue[1].

Results from this study indicate that IGSSA rowers participate in 6-11 hours of rowing related training per week with the number of training hours per week increasing

with age. Whilst high levels of physical activity are generally considered to have a positive impact on physical and mental health[8], people who participate in either low and high levels of physical activity are considered to be at greater risk of LBP. As medium levels of physical activity are considered as protective it has been proposed that a U-shaped relationship between physical activity and LBP incidence exists[16, 28]. The high incidence of LBP reported in this study provides support to the high physical activity component of this hypothesis.

Whilst previous research examining physical activity and LBP has typically quantified the absolute number of hours of physical activity[27, 29] it is also important to consider the type of movement patterns involved[20]. From data collected in this study it was revealed that most of the training time was spent on-water and was conducted in sweep boats. Sweep rowing has been previously considered to load the lumbar spine greater than scull rowing[15, 32] and it can be speculated that the increased risk of LBP is due to the addition of axial rotation to the already seated and flexed lumbar spine[2, 13]. However, recent research examining this issue have not found sweep rowing to be of greater risk than scull rowing[44]. In this study, sweep rowing in eights was revealed as one of the most common factors for bringing-on or exacerbating LBP in rowers.

Rowers in this study also indicated that a majority of the off-water training was conducted on a rowing ergometer which is a known risk factor for LBP in international[44] and collegiate rowers[42]. Previous research[42, 44] has suggested that the emphasis on ergometer training should be on cardiovascular conditioning, rather than strength training, however, in an effort to reduce the incidence of LBP in this group of rowers, cardiovascular conditioning may be improved via cross-training activities such as circuit training, running and cycling. Also related to this is the fact that a large proportion of subjects (approximately 66%) indicated they spent less than five hours per week with other sporting interests indicating that most rowers during the season choose only to row. This may demonstrate the need for rowing programs in this competition to be expanded to include pre- and in-season conditioning as it cannot be assumed that this cohort are generally conditioned by participation in other sporting pursuits.

With the time rowers are required to be in a seated posture for rowing training and competition (and throughout the school day) and the fact that sitting was reported as a habitual factor (in the revised Oswestry questionnaire) that exacerbated the pain, is a matter of concern. These findings provide some support for the fact that this time in sitting is a matter of concern that has been previously identified as a risk factor for LBP[7, 38]. Posture education that addresses day-to-day and rowing-specific applications

therefore should be considered as an important component of any LBP intervention program in schoolgirl rowers. Such an education may also be extended to incorporate training on how to lift correctly. Rowers in this study reported lifting rowing shells and lifting in habitual activities (revised Oswestry questionnaire) as factors that brought on, or exacerbated the LBP.

Whilst this study has provided some interesting findings on a unique sporting group, the conclusions of the study should be considered with the limitations of the study in mind. Firstly, individual physical risk factors such as deficits in back and leg muscle endurance, hamstring flexibility, deficits in motor control resulting in increased flexion strain, adopting habitual postures such as slump sitting and joint hypermobility were not examined in this study. Further, LBP is widely considered as a bio-psycho-social phenomena[43] therefore, individual physical risk factors and psycho-social factors may be important in the aetiology of LBP in this group. These factors should be considered in subsequent investigations. In addition, LBP incidence data were only collected at one point during the season (mid-season). Previous research has shown that LBP incidence fluctuates throughout the season[5]. Future work should involve collecting measures of LBP (incidence, pain and disability) at multiple points throughout the season. Also, the time of day that subjects got the LBP could also be examined, as it may be worse in the morning when disc hydration levels are high. Finally, the findings in this study are gender, age and ability-level specific therefore, generalisation of these findings to rowers in general should be made with caution.

2.6 CONCLUSION

LBP is common in schoolgirl rowers and there is evidence that subjects have moderate levels of pain and clinically significant levels of LBP-related disability. These findings are of concern as the first episode of LBP is a risk factor for LBP later in life. In addition, the sudden training load applied to rowers that are new to the sport when combined with the mechanical loading specific to rowing (a seated sport combining flexion and/or rotation) may increase the risk of LBP. There are several other mechanical factors (training time, rowing in sweep boats, sitting, lifting) that bring on or exacerbate LBP in schoolgirl rowers and coaches and school administrators need to be mindful of these. Further research that examines other factors that may be associated with LBP in rowers (eg. psycho-social factors and individual factors) should be

undertaken and a multi-dimensional approach to prepare the rower's body for this increased load should be considered.

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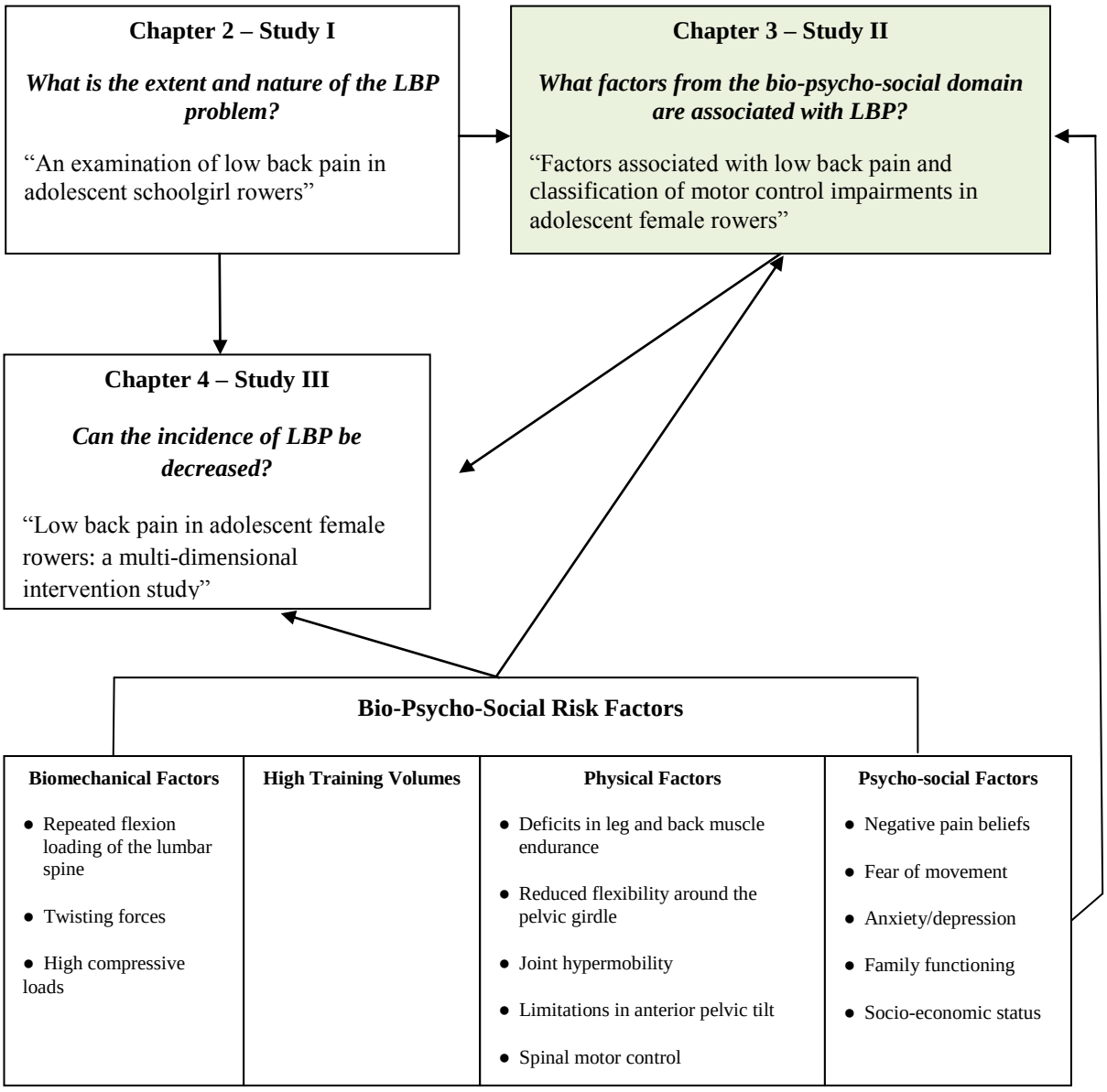
CHAPTER 3 – STUDY II

"Factors associated with low back pain and classification of motor control impairments in adolescent female rowers"

Findings from Study I suggested that low back pain (LBP) was common for rowers participating in the Schoolgirls rowing population in Western Australia. These findings indicated that further investigation was warranted in an attempt to determine the factors from the bio-psycho-social domain that are associated with LBP in this cohort.

The general aims of the study were to investigate differences in physical and psycho-social factors in schoolgirl rowers with and without LBP, and to describe the patterns of motor control impairment present in those with LBP.



This chapter is presented in the pre-publication format of the following article:

Perich D, Burnett A, Dankaerts W, O'Sullivan P. Factors associated with low back pain and classification of motor control impairments in adolescent female rowers, *Submitted.*

3.1 ABSTRACT

This study was undertaken firstly, to determine whether differences existed between schoolgirl rowers with and without low back pain (LBP) for a range of physical tests and psycho-social variables and secondly, to classify the patterns of motor control impairment in LBP participants.

Participants included 60 schoolgirl rowers (30 LBP and 30 without-LBP) between the ages of 14-17 years. Levels of LBP pain and LBP-related disability, psycho-social variables, level of physical activity and a battery of physical tests were assessed. Participants with LBP (N=23) were sub-classified by two experienced musculoskeletal physiotherapists, based on the pain provocative movement and postural patterns.

LBP subjects had significantly reduced back muscle endurance ($p<0.05$) and lower limb endurance ($p<0.01$). The majority of LBP subjects were classified with 'flexion' or 'multi-directional' pain provocation with associated motor control deficits. LBP patients sub-classified with a 'flexion' or 'multi-directional' pain disorder had significantly increased general joint hypermobility ($p<0.05$). LBP subjects and LBP subjects sub-classified with 'flexion' or 'multi-directional' pattern of pain provocation displayed some differences in the repositioning error of the upper lumbar spine ($p<0.05$).

The results of this study may offer some insight into the mechanism of LBP in rowers as well as inform LBP prevention and treatment strategies.

3.2 INTRODUCTION

Previous evidence exists to suggest that low back pain (LBP) is common in rowers[4, 14, 33, 34, 40]. A previous cross-sectional study[33] found that of 356 schoolgirl rowers surveyed, 47.5% had LBP compared with 15.5% of 496 matched non-rowing schoolgirls. These statistics are concerning as LBP in adolescence is a risk factor for LBP in later life[13].

It can be hypothesised that multiple factors may contribute to LBP in rowing and these factors may include; rowing specific factors such as excessive training volume[43], rowing technique (sweep or scull rowing)[37], repetitive flexion and axial rotation of the trunk while rowing[37, 38]. Individual factors may include motor control impairments of the trunk[1], deficits in spinal proprioception[25], increased joint hypermobility[11], and reduced lower limb endurance[41, 46] and back muscle endurance[23, 36]. Psycho-social factors have also been reported to be linked to adolescent LBP potentially resulting in increased tissue sensitisation to spinal loading[20]. These factors are consistent with calls to investigate adolescent LBP from a bio-psycho-social perspective[49].

Whilst there is evidence of altered motor control in LBP disorders[15-17, 24, 30], the pattern of motor control may vary[24]. Hence, O'Sullivan developed a classification system to sub-group patterns of motor control impairment in those with non-specific chronic LBP. Five distinct sub-groups have been described based on the direction of pain provocation and these can be reliably identified by experienced musculoskeletal physiotherapists[9, 47]. The patterns include; the flexion pattern, passive extension pattern, active extension pattern, lateral shift pattern and the multi-directional pattern. Identifying these sub-group types in rowers may offer insight into underlying mechanisms of LBP as well as inform related LBP prevention and treatment strategies.

Therefore, the aims of this study were twofold; firstly to determine physical and psycho-social variables associated with LBP in schoolgirl rowers and secondly, to describe the patterns of motor control impairment present in those with LBP.

3.3 MATERIALS AND METHODS

3.3.1 Participants and Experimental Protocol

This study recruited 60 schoolgirl rowers (30 LBP, 30 no-LBP) aged 14-17 years. Inclusion criteria included; 1) rowed sweep and scull boats in the schoolgirls rowing season and 2) LBP participants had a level of LBP > 3/10 and a disability score > 12% at the start of competition. These scores indicate moderate levels of pain[6], and clinically significant levels of functional disability respectively.

Two weeks prior to completion of the rowing season, participants answered a series of questionnaires addressing psycho-social issues and levels of physical activity. Further, a series of physical tests were completed. Those with LBP also had the beliefs about physical activity assessed[48].

Two weeks post-season, a comprehensive subjective and physical examination was conducted to sub-classify LBP participants[30]. Subject recruitment details and experimental protocol is outlined in Figure 3.1. Permission to conduct the study was granted by the Institutional Human Research Ethics committee (Appendix A).

3.3.2 Measures and Procedures

3.3.2.1 Pain and Disability Measures

The usual level of LBP and level of LBP whilst rowing was determined using the 10cm VAS which has shown to be reliable and valid[31]. The level of LBP-related disability was measured using the revised Oswestry Questionnaire (Appendix D). This questionnaire has been determined to be reliable and valid measure of function[18].

3.3.2.2 Psycho-social Measures

The Back Beliefs Questionnaire (Appendix E) was used to assess beliefs about back pain. This questionnaire has been found to be suitable for patients with LBP and also for workers with and without LBP[44, 45]. Pilot testing conducted on this group of rowers (N=60) revealed good internal consistency (Cronbach's alpha value of 0.735). The questionnaire has 14 items with responses ranging from 1 (Completely Disagree) to 5 (Completely Agree). Scores range between 9-45 with five statements acting as distracters. Lower scores represent more negative beliefs of an individual toward low back trouble.

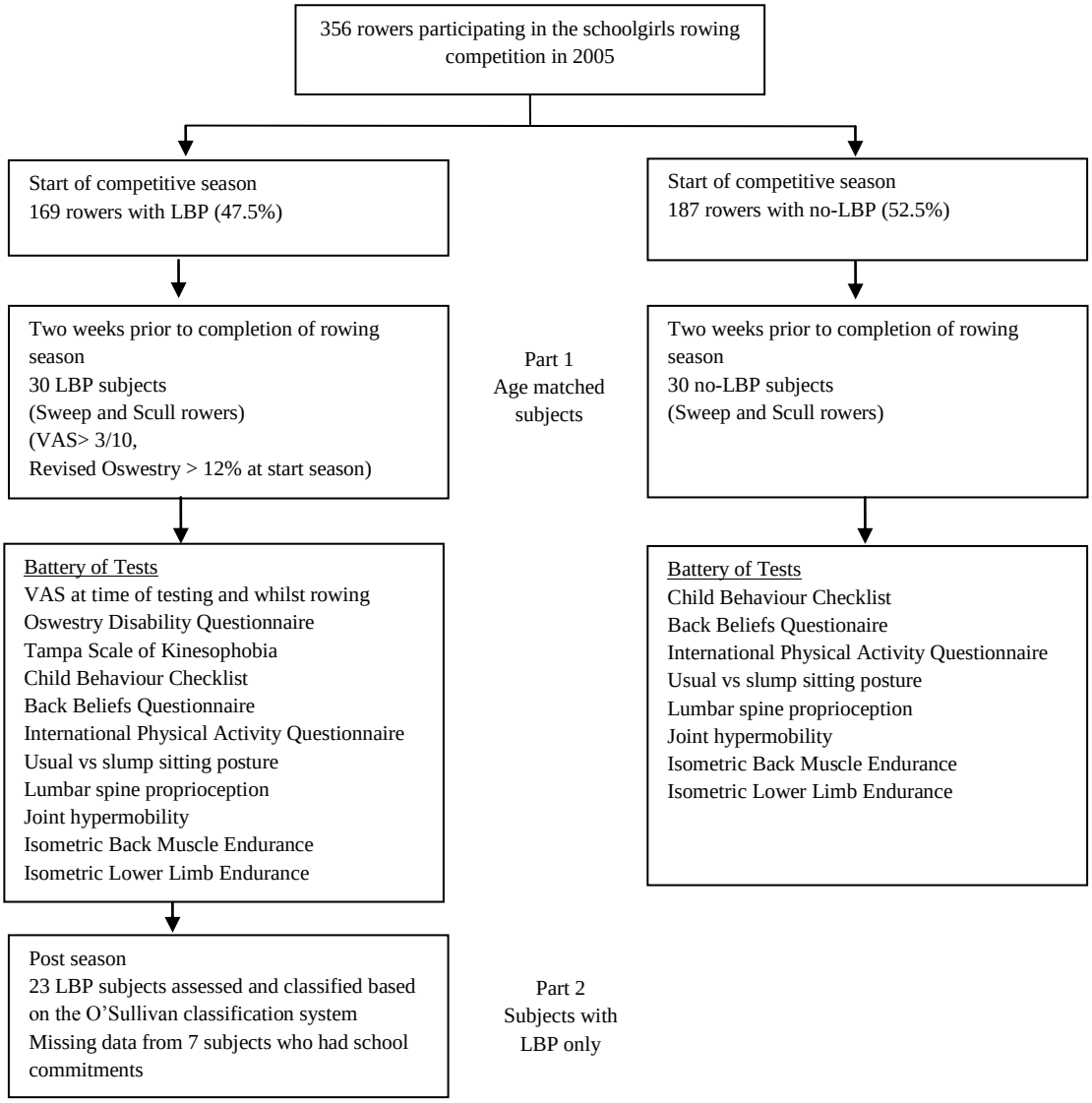


Figure 3.1 Source of the sample and experimental protocol

The Child Behaviour Checklist (Appendix F) is a reliable and valid tool to assess social competence and behaviour problems in children aged 6-18 years[12]. This self-report questionnaire contains 118 items each scored on a 3-point scale ranging from "not true" to "often true". Its eight scales consist of somatic complaints (eg. headaches, stomach ache), withdrawn behaviour, anxious/depressed behaviour, social problems (eg. making friends), thought problems, attention problems, delinquent behaviour and aggressive behaviour. A qualified psychologist assessed all questionnaires and identified "at-risk" participants using associated cut-off scores.

The Tampa Scale for Kinesiophobia questionnaire (Appendix G) was used to measure beliefs about physical activity. This questionnaire consists of 17 items and utilises a Likert-type scale with 1 representing strongly disagree and 4 representing strongly agree[48].

3.3.2.3 Physical Activity Measures

The short form of the International Physical Activity Questionnaire (Appendix H) was used to quantify physical activity levels. This self-report questionnaire is known to be age-appropriate for participants in this study[5]. Questions related to physical activity during the last week and results provide information on the types of physical activity undertaken. For each question, participants indicated the frequency of the particular activity as "days per week", and the "hours per day" or "minutes per day".

3.3.2.4 Physical Tests

Usual and slump sitting posture, lumbar spine proprioception, joint hypermobility, an isometric back muscle endurance test and an isometric lower limb endurance test were assessed in this study.

Lumbo-pelvic kinematic data in usual and slump sitting postures and lumbar spine proprioception were recorded using an electromagnetic tracking system (3-Space Fastrak™;-Polhemus, Vermont). This device has been shown to have an accuracy of 0.2° [32]. For each participant, sensors were placed over the spinous processes of T12, L3 and S2 and data were collected at 25Hz.

3.3.2.4.1 Usual and Slump Sitting

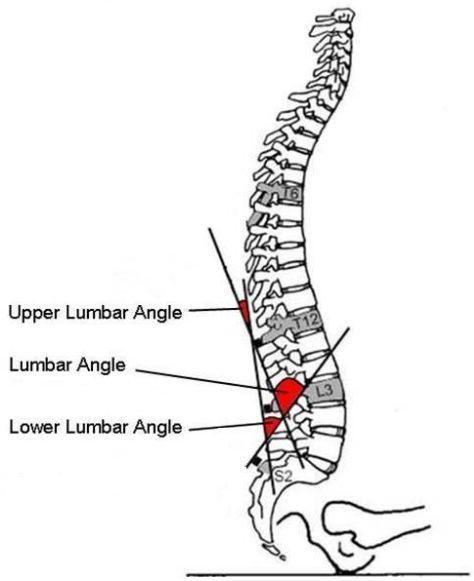
Participants sat on a stool in the usual manner, with knees flexed at 90°. No indication of how to sit or what was being measured was provided. Subjects were then

assisted by an experienced physiotherapist using standardised cues into the end of range lumbar flexion sitting posture (slump sitting)[27]. Mean lumbar angle in this posture was determined over a three second period in both usual and slump sitting positions. Customised software was written to determine lumbar spine angles for sensors overlaying T12, L3 and S2.

3.3.2.4.2 Lumbar Spine Repositioning Sense

Lumbar spine repositioning sense was evaluated with participants attempting to reproduce a criterion position of neutral lordosis in sitting[25]. Participants sat on a stool with feet positioned shoulder width apart and arms hanging relaxed next to the thighs. Participants were blindfolded and assisted through the available range of lumbar flexion and extension three times. Participants were then positioned into neutral lordosis with an upright trunk position for a period of five seconds and instructed to remember this position. Participants were then asked to relax into full lumbar flexion for five seconds before being asked to reproduce the criterion position. This protocol was followed until three repositioning tests were completed. Microsoft Excel was used to determine lumbar repositioning (displacement) and repositioning errors for the lumbar spine angles in degrees between the Fastrak sensors at T12, L3 and S2 using matrix algebra procedures outlined in Appendix I.

The repositioning error (RE) was defined using the resultant of the cartesian coordinates[25]. RE was calculated by averaging the values of the three sensors. Three measures relating to lower lumbar, upper lumbar and lumbar angles (Figure 3.2) were used to estimate repositioning ability; constant error (CE), absolute error (AE) and variable error (VE). CE is a measure of bias considered as the signed difference between the criterion and finish positions, with a positive CE indicating overshooting of the criterion position. AE is the unsigned difference between the criterion and the finish positions and reflects repositioning accuracy only[42]. AE and CE were averaged over three trials. VE represents the variability of an individual's CE measure and represents repeatable precision. In this study VE was calculated as the SD of the three trials of CE of the one individual[2]. High VE reflects high variability in repositioning ability, whilst low VE reflects low variability of positioning.



Lower Lumbar Angle – the angle between two intersecting lines, one indicating the inclination of the sensor at L3 and the other the inclination of the sensor at S2. A negative lower lumbar angle indicates lumbar lordosis. **Upper Lumbar Angle** – the angle between two intersecting lines, one indicating the inclination of the sensor at T12 and the other the inclination of the sensor at L3. A negative angle indicates lumbar lordosis. **Lumbar Angle** – the angle between two intersecting lines, one indicating the inclination of the sensor at T12 and the other the inclination of the sensor at S2. A negative angle indicates lumbar lordosis.

Figure 3.2: Spinal kinematics variables

3.3.2.4.3 *Joint Hypermobility*

Joint hypermobility was measured using the reliable and valid Beighton scale[10]. Joints measured were bilateral metacarpophalangeal extension > 10°, bilateral knee extension > 10° and palms flat on the floor from a standing position with knees extended. For each joint that fulfils the criteria, one point is allocated, giving a total of nine points.

3.3.2.4.4 *Isometric Back Muscle Endurance*

Isometric back muscle endurance was assessed using the Beiring-Sorenson test[3]. The upper body was cantilevered out over a test bench with the lower limbs secured. The length of time (in seconds) subjects were able to maintain neutral trunk alignment without deviating more than 10° into flexion was recorded.

3.3.2.4.5 *Isometric Lower Limb Endurance*

A measure of isometric lower limb endurance was taken using a single trial semi-squat hold test[21]. Subjects were seated on a stool with thighs parallel and knees flexed at 90° and the arms folded across the chest. Subjects were then asked to adopt a squat position with the buttocks just clear of the stool. The length of time (in seconds) a subject was able to maintain this position was measured.

3.3.2.4.6 *Classification of Motor Control Impairment*

Two weeks post-season, 23/30 LBP subjects were assessed by two experienced musculoskeletal physiotherapists in order to classify them based on the O'Sullivan classification system[30]. Seven LBP subjects were unable to be assessed due to school commitments. The classification process involves a comprehensive subjective and physical examination to identify the pattern of motor control impairment related to the direction of pain provocation (Table 3.1). It has been shown to be reliable between physiotherapists trained in the system[9, 47].

3.3.2.5 Statistical Analysis

Independent t-tests determined whether differences in characteristics existed between the LBP and no-LBP groups and between the no-LBP group and the merged flexion/multi-directional pattern group (see section 3.4.1). Cohen's d (effect size index) was also calculated between these groups. All statistical analyses were undertaken using SPSSV16 for Windows (SPSS Inc., Chicago: USA) and the level of significance for all tests was set at $p<0.05$.

Table 3.1: Subgroups of the O'Sullivan's classification system – motor control impairments (MCI) and the clinical presentation[9, 24, 30]

	Flexion Pattern	**Flexion/lateral shifting pattern**	**Active Extension Pattern**	**Passive Extension Pattern**	**Multi-directional Pattern**
Definition	MCI of the lumbar spine with a tendency to flexion strain (loss of segmental lordosis) at the symptomatic segment. Flexion pain disorders are associated with functional loss of motor control into flexion resulting in an excessive abnormal flexion strain.	MCI around the lumbar spine with a tendency to flex and laterally shift at the symptomatic segment.	MCI around the lumbar spine with a tendency to hold the lumbar spine actively into extension.	MCI around the lumbar spine with a tendency to passively over-extend at the symptomatic segment of the lumbar spine.	Multi-directional MCI around the lumbar spine
Provocative postures/activities	All flexion-related postures (eg. slouch sitting) and functional activities (eg. forward bending, cycling) are commonly reported as being painful.	Reaching and rotating in one direction in association with flexion postures and/or movements.	All extension-related postures (standing, erect sitting) and functional activities (carrying out overhead activities, fast walking, running and swimming) are commonly reported as being painful.	Similar to the active extension pattern all extension-related postures (standing, erect sitting) and functional activities (carrying out overhead activities, fast walking, running and swimming) are commonly reported as being painful.	Multi-directional nature of this pattern often reveals pain in all weight bearing postures and functional activities.
Easing postures/activities	Extension postures/activities in which the lumbar spine is lordosed (eg. standing, sitting with a lumbar roll, walking).	Relief in extended or lordotic postures, stretching to the opposite side from the shift, shift correction.	Flexion postures/activities in which the lumbar spine is flexed (eg. crook lying, slouched sitting).	Flexion postures/activities in which the lumbar spine is de-lordosed (eg. crook lying, slouched sitting).	Difficulty to find relieving postures during weight bearing
Posture and movement analysis	Tendency to present with a loss of lumbar lordosis during sitting and standing postures. The pelvis is often positioned in a posterior tilt. During all functional tasks the same tendency to have a loss of lordosis at the 'symptomatic level' is noted.	Similar to the flexion pattern there is a loss of lumbar segmental lordosis at the affected level with the key feature here an associated lateral shift at the lower lumbar spine level.	Tendency for the lumbar spine to be actively held into segmental hyper-lordosis at the symptomatic segment during upright sitting and standing postures. During all functional tasks such as sit to stand, squatting and forward bending the same tendency to hyper-lordose at the 'symptomatic segment' is noted.	Tendency for patients to stand into a sway-back posture (thorax posterior to the pelvis) with a segmental hinging at the symptomatic level. Forward bending is often pain free, but on return to neutral they tend to over-extend at the symptomatic level (hinge into extension) and sway pelvis anterior.	Patient may assume a flexed, extended, or laterally shifted spinal posture, and may frequently have to alternate them. Excessive segmental shifting and hinging may be observed in all directions, with associated 'jerky' movement patterns and reports of 'stabbing' pain on movement in all directions.
Specific posture and movement control tests	Inability/lack of motor control to anterior rotate pelvis and extend lower lumbar spine independent from thorax during abovementioned aggravating postures/movements.	Inability/lack of motor control to anterior rotate pelvis and extend lower lumbar spine independent from thorax during above-mentioned aggravating postures/movements with an associated lateral deviation.	Inability/lack of motor control to initiate a posterior pelvic tilt during the abovementioned aggravating postures/movements.	Inability/lack of motor control to extend the thoraco-lumbar spine above the symptomatic segment with a tendency to hinge into extension at this segment.	Patients have great difficulty assuming neutral lordotic spinal postures, with over shooting into flexion, extension or lateral shifting postures.

3.4 RESULTS

3.4.1 Classification of Motor Control Impairment

Subjects were reported to have a flexion (N=10) or multi-directional pattern (N=9) whilst four had an active extension control disorder. Since flexion control impairments are common to both the flexion and multi-directional patterns these participants were grouped for analysis.

No significant differences were evident between the groups with regards to age, body mass index, amount of physical activity and back beliefs (Table 3.2).

3.4.2 Pain and Disability Measures

Rowers with LBP reported the pain (mean±SD) whilst rowing in the week prior to testing to be 5.8±1.9 (as indicated by the VAS) and the pain at the time of testing to be 2.2±1.9. The sub-classified LBP participants (pooled flexion/multi-directional) reported the pain whilst rowing to be 6.4±1.5 and the pain at the time of testing to be 2.4±2.0. The Oswestry disability score for the LBP group was 28.9%±11.6 and for the sub-classified flexion and multi-directional control deficit participants was 31.3%±12.7. No significant differences evident between these groups

3.4.3 Psycho-social Questionnaires

No significant differences ($p<0.05$) or d-values > 0.5 were evident between the no-LBP and either of the LBP groups for total score from the Child Behaviour Checklist (No LBP/ LBP, $p=0.63$, Cohen's d = 0.13; No LBP/sub-classified with flexion/multi-directional subgroup, $p=0.26$, Cohen's d= 0.32) or the eight scales of the questionnaire (range of p-values for No LBP/LBP 0.292-0.952; range of Cohen's d values 0.08-0.29; range of p-values for No LBP/sub-classified with flexion/multi-directional control deficits 0.132-0.955, range of Cohen's d values 0.05-0.45). Whilst, cell sizes were too small to perform chi-square analyses a greater proportion of the rowers with LBP were clinically classified as either borderline-at risk or, clinically at risk with the behaviours. These proportions were amplified in the LBP participants sub-classified with flexion and multi-directional subgroups (No LBP 3.3%, LBP 13.3%, sub-classified flexion and multi-directional control deficits 21.1%). The Child Behaviour Checklist data have been provided in Appendix J. Data from the Tampa Scale indicated a low degree of kinesiophobia[48] for the LBP group (19.2±3.5) and the sub-classified group (19.1±3.6).

3.4.4 Physical Activity Measures

No significant differences were evident between the no-LBP and either of the LBP groups for participation in physical activity (Table 3.2).

3.4.5 Physical tests

Mean (±SD) data for physical tests are presented in Table 3.3. Significant differences were evident between no-LBP and LBP groups for physical testing with the LBP groups displaying deficits in lower limb endurance and back muscle endurance. The only kinematic difference was a reduction in range of pelvic tilt (sacral angle) between usual and slump sitting observed in the pain groups.

Mean (±SD) data for repositioning error of the lumbar spine are presented in Table 3.4. Significant differences were shown for the CE for the upper lumbar angle between rowers with and without LBP ($p=0.038$) and sub-classified LBP rowers ($p=0.029$) with the LBP groups displaying less CE. No significant differences were shown for the AE. Significant differences were shown for the VE between rowers with and without LBP ($p=0.008$) and the sub-classified LBP group ($p=0.019$) with the LBP groups displaying greater variability in repositioning error.

A significant increase ($p=0.031$) in general joint hypermobility was evident between rowers with flexion or multi-directional deficits and the no-LBP subjects.

Table 3.2: Characteristics for subjects (mean ± standard deviation) for the no-LBP and LBP groups.

	No LBP (N=30)	**LBP (N=30)**	**p-value**	**Cohen's d**	**LBP Flexion and Multi-directional (N=19)**	**p-value**	**Cohen's d**
Age (years)	15.2 ± 1.1	15.1 ± 1.2	0.767	0.09	15.3 ± 1.3	0.862	0.08
Body Mass Index	20.4 ± 2.4	20.9 ± 2.3	0.397	0.21	21.1 ± 2.6	0.297	0.28
Physical Activity (METS min/week)	5626.9 ± 2798.8	6228.0 ± 4151.5	0.583	0.17	5150.4 ± 2864.9	0.621	0.17
Back Pain Beliefs	29.0 ± 5.6	29.7 ± 4.9	0.649	0.13	30.1 ± 5.2	0.524	0.20

Table 3.3: Physical testing data, mean (standard deviation) for the no-LBP and LBP groups. Lumbo-pelvic posture data are presented in usual and slump sitting and the difference between the two postures. For lumbo-pelvic data positive values indicate a flexed posture while negative values indicate an extended posture.

	No LBP (N=30)	**LBP (N=30)**	**p-value**	**Cohen's d**	**LBP flexion and multi-directional (N=19)**	**p-value**	**Cohen's d**
Lower Limb Endurance (sec)	73.6 (28.7)	48.3 (27.7)	0.001**	0.90	46.6 (24.3)	0.001**	1.02
Back Muscle Endurance (sec)	106.0 (55.2)	79.1 (44.2)	0.040*	0.54	73.7 (42.1)	0.028*	0.66
Joint Hypermobility (/9)	2.1 (1.9)	2.9 (2.2)	0.136	-0.39	3.4 (2.5)	0.031*	-0.59
Pelvic Tilt – Usual Sit (°)	-2.8 (9.7)	-7.2 (9.0)	0.073	0.47	-5.6 (9.6)	0.335	0.29
Lower Lumbar Angle – Usual Sit (°)	4.0 (9.8)	7.2 (9.2)	0.206	-0.34	0.4 (20.0)	0.404	0.24
Upper Lumbar Angle – Usual Sit (°)	-1.1 (7.5)	-1.7 (6.6)	0.779	0.09	-6.6 (14.8)	0.094	0.49
Pelvic Tilt – Slump Sit (°)	5.0 (10.2)	8.0 (11.0)	0.271	-0.28	6.3 (10.8)	0.661	-0.12
Lower Lumbar Angle – Slump Sit (°)	-10.2 (9.7)	-11.1 (9.4)	0.720	0.09	-11.3 (10.6)	0.707	0.08
Upper Lumbar Angle – Slump Sit (°)	-10.5 (7.1)	-12.9 (10.5)	0.292	0.27	-14.2 (12.7)	0.192	0.37
Pelvic Tilt Difference (°)	7.8 (9.9)	15.2 (13.9)	0.020*	0.62	11.9 (13.5)	0.221	0.35
Lower Lumbar Difference (°)	14.4 (10.1)	18.5 (11.7)	0.156	-0.38	11.7 (22.7)	0.569	0.17
Upper Lumbar Difference (°)	9.6 (6.9)	11.4 (10.9)	0.458	-0.20	7.6 (18.6)	0.597	0.16

Note: * indicates a significant difference ($p<0.05$) between rowers with LBP/sub-classified rowers with LBP and rowers with no LBP
** indicates a significant difference ($p<0.01$) between rowers with LBP/sub-classified rowers with LBP and rowers with no LBP

Table 3.4: Lumbar repositioning (cms) and repositioning errors (CE, AE, VE) for each trunk angle (degrees) for each group
Values are mean ± SD, CE = Constant Error, AE = Absolute Error, VE = Variable Error.
A negative value represents an overshoot of the criterion position.

	No LBP (N=30)	**LBP (N=30)**	**p-value**	**Cohen's d**	**LBP flexion and multi-directional (N=19)**	**P-value**	**Cohen's d**
Lumbar Repositioning (cms)	2.8±2.4	2.2±2.0	1.315	0.27	2.0±1.7	0.183	0.39
Lumbar Angle (degrees)							
CE	3.3±4.8	0.8±5.6	0.079	0.48	0.4±5.0	0.053	0.59
AE	5.5±2.7	5.9±3.0	0.588	0.14	5.4±2.8	0.883	0.04
VE	4.0±2.6	5.2±3.1	0.118	0.42	5.1±3.2	0.204	0.38
Lower Lumbar Angle (degrees)							
CE	1.9±3.5	0.7±4.6	0.256	0.30	0.5±4.3	0.217	0.36
AE	3.8±1.9	4.2±2.6	0.450	0.18	4.0±2.3	0.707	0.10
VE	2.7±1.7	3.4±2.6	0.184	0.33	3.2±2.0	0.373	0.27
Upper Lumbar Angle (degrees)							
CE	1.3±2.3	0.1±2.3	0.038*	0.52	-0.2±2.3	0.029*	0.75
AE	2.5±1.3	2.6±1.3	0.715	0.08	2.6±1.4	0.847	0
VE	1.7±1.2	2.8±1.8	0.008*	0.73	2.9±2.1	0.019*	0.73

Note: * indicates a significant difference ($p<0.05$) between rowers with LBP/sub-classified rowers with LBP and rowers with no LBP

3.5 DISCUSSION

Previous studies[33, 34] demonstrating LBP is common in this group indicate that further investigation is required to identify associated factors with LBP.

Differences were found between the no-LBP group and both LBP groups for both lower limb and back muscle endurance with the pain groups displaying poorer endurance. Lower limb endurance is considered an important factor for rowing performance[19] as the legs initiate and assist in the drive phase of the rowing stroke. If the legs are prematurely fatigued the rower's back may then be the main contributor to produce force on the oar and accelerate the rowing shell. There is evidence of such a substitution pattern in repetitive lifting[39]. Reduced lower limb muscle endurance has also been found as a physical characteristic existing prior to low back injury[41, 46].

Poor back muscle endurance may also render the spine vulnerable to increased tissue strain. Possible causes of reduced back muscle endurance may include poor general conditioning, altered motor control patterns[28, 29] or habitual positioning of the spine in postures associated with reduced activity of the back muscles[28]. However the lack of clear postural differences between the groups highlights the need to investigate spinal kinematics in functionally provocative positions such as on a rowing ergometer.

Deficits in spinal repositioning sense have been previously reported to be associated with LBP[26]. No significant differences were evident between the LBP and no-LBP groups for the lumbar repositioning when considering the lumbar spine as a whole. However some deficits were identified when regional spinal differences in the spine were investigated. This highlights the need for examining regional differences[22], where the greater variability in repositioning error identified in the back pain groups for the upper lumbar spine may represent a vulnerability of the lumbar spine to tissue strain. It was also noted that LBP participants took longer to complete the repositioning task highlighting the need to control for time in future investigations.

Joint hypermobility has previously been reported as a risk factor for LBP in adolescent girls[11]. LBP participants displayed a non-significant increase in general joint mobility when compared with those with no-LBP however, a significant difference for general joint hypermobility was found for sub-classified subjects. This finding emphasises the importance of sub-classification where active extension patients have shown to present with a decreased range of spinal motion when compared with those with a flexion pattern[7, 8]. It is considered that generalised joint laxity may reflect a deficit in the spine's passive stabilising structures to transmit loads effectively[11].

Whilst psycho-social problems have been previously linked to the development and presence of adolescent back pain[35], no differences in psycho-social variables were found in this study. However, there was some suggestion that psycho-social factors could still be of interest in further investigations in this cohort. Specifically, even though no statistical tests were undertaken due to small cell sizes, an increased proportion of rowers with LBP were classified as being "at-risk".

3.5.1 Limitations

This investigation examined schoolgirl rowers so results cannot be generalised to schoolboys and older, and higher level rowers. Further, cause and effect cannot be determined due to the cross sectional design of this study and small number of participants may increase the chance of error using repeated t-tests. Finally, there were a lack of measures to validate the classification of the LBP subjects and ergonomic analysis in future research would add value to the classification.

3.5.2 Clinical Implications

While it is well known that the incidence of LBP in rowers is high, there is little research that has examined factors related to LBP in schoolgirl rowers. Identifying potential modifiable risk factors and subgroups may lead to better management strategies.

An intervention program that addresses impairments in spinal position sense and endurance of the leg and back muscles, whilst also monitoring the duration of on water and ergometer training may be of benefit in reducing the prevalence of LBP in this cohort. This is the focus of ongoing investigations.

3.6 CONCLUSIONS

The majority of rowers with LBP were clinically classified with deficits in flexion or multi-directional segmental spinal control. Factors associated with LBP in this group were reduced lower limb and back muscle endurance, and a general pattern for less accuracy and greater variability in repositioning sense. This sub-classified LBP group also displayed greater joint hypermobility when compared with those with no-LBP. Although the question of cause and effect cannot be answered without a

prospective study design, the current study may provide preliminary evidence for a multi-dimensional intervention strategy to decrease the prevalence of LBP in this group.

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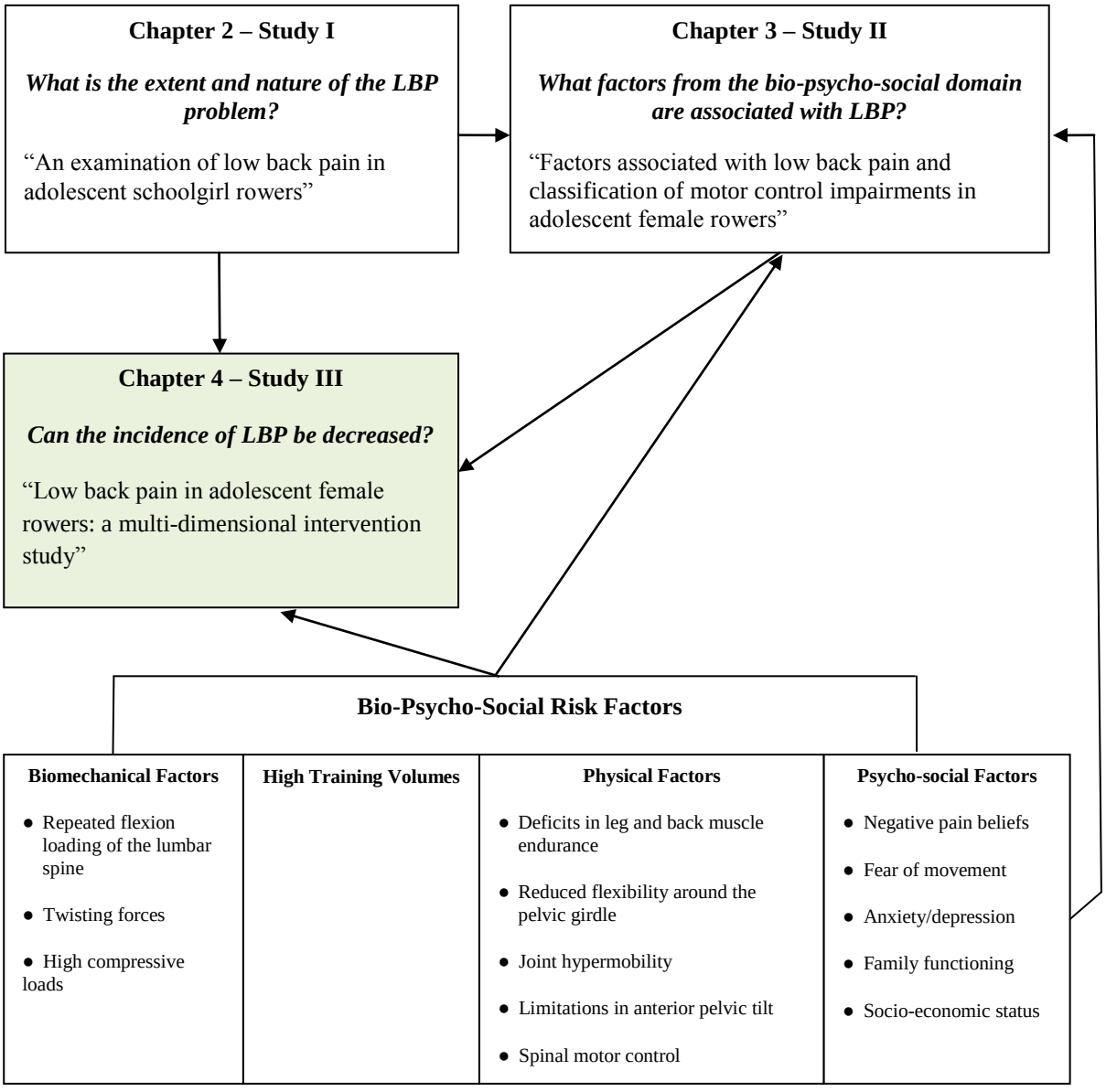
CHAPTER 4 – STUDY III

"Low back pain in adolescent female rowers: A multi-dimensional intervention study"

Findings from Study I and Study II provided information to guide the development of an intervention program and these became the focus of ongoing investigations in this study.

The general aims of this study were to examine whether a multi-dimensional intervention program can decrease the incidence of LBP and the associated levels of pain and disability in schoolgirl rowers, and to examine the changes in secondary variables within a bio-psycho-social framework in the rowers participating in the intervention program.



This chapter is presented in the pre-publication format of the following article:

Perich D, Burnett A, O'Sullivan P, Perkin C. Low back pain in adolescent female rowers: A multi-dimensional intervention study. In Press, *Knee Surgery, Sports Traumatology, Arthroscopy*.

4.1 ABSTRACT

The aim of this study was to determine whether a multi-dimensional intervention program was effective in reducing the incidence of low back pain (LBP) and the associated levels of pain and disability in schoolgirl rowers. This non-randomised controlled trial involved an intervention (INT) group consisting of 90 schoolgirl rowers from one school and a control (CTRL) group consisting of 131 participants from three other schools. All participants in the INT group underwent a multi-dimensional program that consisted of an individualised exercise program based on an individual musculoskeletal screening (Week 1) and a LBP education session conducted by a Physiotherapist (week 2), and performed an off-water conditioning program conducted by a Physical Education Teacher. All exercises were undertaken during the season.

Primary outcome variables collected at Start-season, Mid-season, End-season and Post-season included the incidence of LBP and related levels of pain and disability. Secondary outcome variables from the bio-psycho-social domain were measured at Start-season and End-season in the INT group only.

The INT group had a lower incidence of LBP at Mid-season and End-season and displayed significantly better results than the CTRL group for improvers and non-improvers with respect to the levels of pain and disability. The INT group following the intervention also displayed improved physical fitness levels, sat with significantly less anterior tilt of the pelvis and lumbar kyphosis when in the usual sitting posture, and demonstrated positive changes in the behaviour.

The multi-dimensional approach to reducing the incidence of LBP, pain and disability in schoolgirl rowers in this study was effective. Several secondary outcome variables measured in the INT group considered to be of importance in LBP significantly improved. These included physical fitness (aerobic conditioning, lower limb and back muscle endurance and sit and reach flexibility) and seated posture (usual and slump sitting).

4.2 INTRODUCTION

High levels of physical activity such as that involved in rowing have been considered to have a positive impact on physical and mental health[9]. However, there is evidence that suggests LBP is common in rowers[4, 10, 19, 20, 40, 41] and it's incidence fluctuates throughout the season as training and competition load vary[4]. Adolescent female rowers in particular may have an increased predisposition to LBP as rowing is a physically demanding sport, and the incidence of LBP increases in adolescence and is more common in females in the general population[5] and in specific sporting populations[6, 24]. Whilst it is reported that 85% of cases of LBP in the general population are non-specific in origin[12] the high incidence of radiological abnormalities of the thoraco-lumbar spine observed among athletes in sports with great loading and movement demands on the spine (such as fast bowling in cricket, wrestling, gymnastics, water-ski jumping, soccer and tennis)[6, 17, 22, 24, 38, 44], supports an overstress mechanism for LBP in this population.

A previous two-part cross-sectional study[37] found that of 356 schoolgirl rowers surveyed, 47.5% had LBP compared to 15.5% of 496 non-rowing schoolgirls. Self-reported rowing-related factors such as long rows in a training session, lifting a rowing shell and rowing in a sweep eight exacerbated the pain. Furthermore, other functional activities such as sitting, lifting and standing were also reported to provoke thepain levels.

In the second part of the representative study examining bio-psycho-social variables that differentiated schoolgirl rowers with LBP from those without[37], it was concluded that the presence of LBP in schoolgirl rowers was associated with reduced lower limb and back muscle endurance. Furthermore, differences were evident in usual lumbo-pelvic and slumped seated posture. No differences were found for any psycho-social variables.

Only a few studies have tested the efficacy of exercise interventions in preventing first-episode or recurrent LBP in sporting populations. Core strengthening is widely used as a method to improve performance[26, 42, 49] and prevent spinal injuries[3, 30]. However, generalised core strengthening exercise interventions previously reported in collegiate athletes[30] and rugby players[11] have not demonstrated a change in LBP incidence. Further, a recent study evaluated specific segmental muscle control exercises in young female gymnasts and demonstrated efficacy in preventing and reducing LBP[15].

In this study however, exercises were not individualised to the athlete. Whilst the above studies are examples of uni-dimensional approaches to injury prevention, multi-dimensional approaches should be considered due to the complex multi-factorial nature of LBP in sport. A recent systematic review examining the effectiveness of preventative interventions in adolescent sport[1] concluded that multi-faceted interventions that consider pre-season conditioning, functional training, education, proprioceptive balance training and sport specific skills which are continued throughout the sporting season are warranted. However, to date the efficacy of this approach has not been investigated.

LBP in adolescence has been found to be a risk factor for subsequent episodes of LBP in later life[18] and participation in organised sports by adolescent females has been considered as a risk factor for LBP hospitalization[25]. Hence, preventative measures to ensure the safe participation of adolescent females in sport is of importance[7]. Therefore, the aim of this study was to determine whether a multi-dimensional intervention program was effective in reducing the incidence of LBP and the associated levels of pain and disability in schoolgirl rowers across a rowing season. We hypothesised that a multi-dimensional intervention would reduce the incidence of LBP and associated levels of pain and disability throughout the course of the schoolgirl rowing season.

4.3 MATERIALS AND METHODS

4.3.1 Participants

Participants in this non-randomised trial included 14-17 year old females who were enrolled in a school-based rowing program in 2006. The intervention (INT) group consisted of schoolgirl rowers from one school (n=90) whilst participants from three other schools (n=131) formed a control (CTRL) group. The details of these groups with respect to training and competition exposure, as well as other sporting activities and socio-economic status were as follows:

Training hours – INT group training hours (mean±SD/week) at the end season were 6.7±0.5, 7.4±0.5, 8.3±1.2 for 14 years, 15 years and 16/17 years respectively. Crews generally trained three to four sessions per week on water and one session per week on land.

Competition Experience – The first year of competition for rowers in this rowing competition association is at 14 years therefore, the range of competitive

experience is typically from 1-4 years. The schoolgirls rowing competition consists of five regattas over the winter months (May to August) culminating with the Head of the River Regatta.

Other Sporting Pursuits – Sixty-eight percent (68%) of the INT group and 61% of the CTRL group participated in less than five hours per week in sporting pursuits other than rowing.

Socio-Economic Status (SES) – Participants in the INT and CTRL groups in this study came from some of the leading Independent Girls' Schools in Western Australia, and hence were of similar socio-economic background. Data from the Australian Government Department of Education, Employment and Workplace Relations shows that the INT school had a SES score of 111 in the SES funding model which links student residential addresses to the Australian Bureau of Statistics national census data. This provides a socio-economic profile for the school community. The SES scores for the CTRL schools ranged from 114 to 125. All scores were well above the average SES score of 98.8 for schools in Western Australia.

Data in this study was collected at four periods throughout the rowing season namely; Start-season (Week 3), Mid-season (Week 12), End-season (Week 21) and Post-season (Week 33). Whilst this study was a controlled trial, LBP incidence data were also collected from rowers from the CTRL group schools who missed data collection at Start-season but still attended the other Mid-season, End-season and Post-season data collection sessions. Hence, a cross sectional sample was also obtained. The flow of participants throughout this trial and details of the cross sectional group are shown in Figure 4.1. Permission to conduct the study was granted by the Institutional Human Research Ethics Committee (Appendix K).

Primary outcome variables included; incidence of LBP and related levels of pain and disability and these data were collected at the abovementioned sessions. Secondary outcome variables from the bio-psycho-social domain included; back muscle endurance, lower limb endurance, aerobic fitness, sitting posture, lumbo-pelvic flexibility, back pain beliefs and child behaviour data. These data were collected at Start-season and End-season for the INT group only.

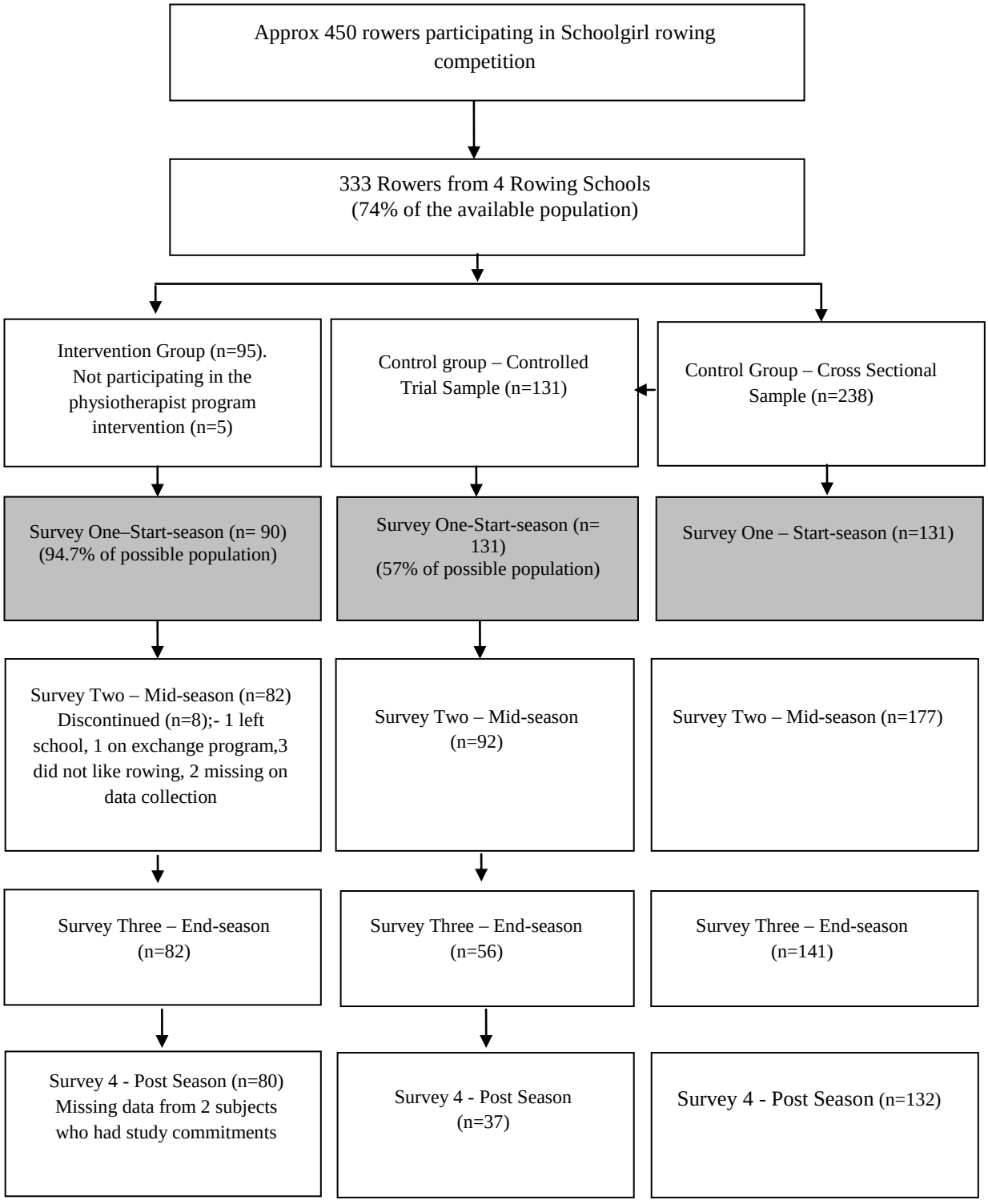


Figure 4.1: Flow of participants during the study

4.3.2 The Intervention Program

The INT group underwent a multi-dimensional intervention consisting of physiotherapy screening, prescription of individualised "specific exercise", follow up sessions, back pain education talk conducted by a Post- Graduate trained Physiotherapist and off-water strength and conditioning sessions conducted by a Physical Education teacher. Details of the program are outlined in Table 4.1. Off-water conditioning sessions were conducted either immediately before or after on-water training sessions with the level of attendance exceeding 90%. The total number of training hours per week for the INT group was not altered from the previous year.

Participants in the CTRL group did not receive any advice from the investigators regarding changing training practices, however, for ethical reasons head coaches of the respective programs were informed of the results of the study conducted in the previous year which demonstrated the high incidence of LBP across the rowing season, and the association between reduced back and lower limb muscle endurance and LBP in schoolgirl rowers[37]. In response to this information, rowing co-ordinators from CTRL schools revealed that the following changes were made to training practices; 1) wheels were added to coaches chase dinghies so that rowers were not required to carry the load as far, 2) pre- and throughout season pilates and aerobics sessions were implemented, and 3) one school reported that they placed an increased focus on core stability and leg strength during off-water training.

4.3.3 Primary Outcome Measures

To assess the level of LBP at the time of data collection and whilst rowing, participants completed a visual analysis score for pain intensity (VAS). The start point was on the left side of the 10 cm horizontal line being "no pain" and the end point at the right side of the line being the "worst pain imaginable". This method of measuring pain intensity has been shown to be reliable and valid[35]. Participants also completed the revised Oswestry Disability Questionnaire to assess the level of LBP-related disability. This questionnaire is a reliable and valid[21] measure of function consisting of nine sections: pain intensity, personal care, lifting, walking, sitting, standing, sleeping, social life and travelling.

Table 4.1: Details of the multi-disciplinary intervention program

COMPONENT	WHO	WHEN/ DURATION	DETAILS OF COMPONENT
1. Initial Musculoskeletal screening Note: The physiotherapists followed a standard assessment protocol and prescribed the same set of exercises for specific deficits. The lead investigator (DP) was blinded to all physiotherapy assessments.	Co-author (CP) and six other experienced post- graduate physiotherapists	Week 1	An interview to assess current and previous history of LBP, pain location, aggravating and easing factors for LBP, as well as treatment history, attitudes towards LBP, current levels of rowing training and general activity. Following this, a musculoskeletal physical examination was carried out in order to examine spinal range of movement, directional pain provocation, habitual spinal postures in sitting and standing and lumbo-pelvic motor control. Lumbo-pelvic motor control was assessed by the ability to maintain a neutral lumbar spine with a relaxed thorax in: sitting whilst performing active hip flexion and knee extension, sitting bending with forward reach, sit to stand, squat with forward reach, seated row position on a rowing ergometer.
2. Individual Specific Exercises conducted by participants with and without LBP (as a result of the initial musculoskeletal screening) – see Appendix M		Throughout the season and performed daily by each rower for approx 10 minutes	For participants with LBP, exercises were designed to address specific deficits in lumbo-pelvic motor control, based on motor control impairments identified on examination as being pain provocative[34]. For participants without LBP, each program addressed motor control deficits which were recognised as having the potential to cause LBP in the subject[34].
3. Back management education	Co-author (CP).	Week 2 – 2 hour session	Education on basic spinal mechanics, injury risk, mechanisms for LBP, spinal posture whilst sitting, rowing and lifting, and attitudes and coping strategies with regards to the management of LBP. Coaches, parents and Physical Education staff were encouraged to attend.
4. Follow up musculoskeletal screening sessions Note: After the initial three visits some participants were seen on more occasions (maximum of six) if the rower had poor lumbo-pelvic control or worsening LBP.	Co-author (CP) and three other experienced post-graduate physiotherapists	Weeks 3 and 7 – 15 minute sessions.	These sessions allowed the physiotherapists to provide feedback on how the exercises were performed and to assess progress. There was a minimum of two follow-up sessions with some rowers requiring five follow-up sessions.
5. Off-water conditioning program (integrated into the training program of the rowers) – see Appendix N	Lead investigator (DP).	Weeks 3-23:- 1.5 hrs/week in weeks 3-12 and 1 hr/week in weeks 13-21	Component was specifically designed to increase lower limb and back muscle endurance and improve aerobic capacity. The training program consisted of aerobic conditioning, hill running, fitness circuits, strength and conditioning circuits and flexibility training. Time was also allocated in each session for rowers to complete the exercise programs prescribed by the Physiotherapists.

4.3.4 Secondary Outcome Measures

4.3.4.1 Physical Fitness

Three tests of physical fitness were utilised. Firstly, isometric back muscle endurance was assessed using the Beiring-Sorenson test[8]. The upper body was cantilevered with the upper and lower legs secured with a seat belt and the length of time neutral trunk alignment was maintained without deviating more than 10° into flexion or extension determined by an inclinometer was recorded using a stopwatch[8]. Secondly, isometric lower limb endurance was measured using an isometric semi-squat posture with the hips and knees postured at 90 degrees and time to maintain this position was measured using a stop watch[27]. Aerobic fitness was tested using a 12 minute run tested on a grass surface[14]. Finally, to assess spinal-pelvic and hamstring flexibility, subjects were asked to reach to the toes as far as they could in long sitting, and the distance from the toes was measured in centimetres, with a negative score indicating that the subject could not reach the toes and a positive score indicating that they could reach beyond the toes.

4.3.4.2 Usual and Slumped Sitting

Sagittal sitting posture was assessed using digital photography and retro-reflective markers. Seven retro-reflective markers on the following surface landmarks on the right side of the body were digitised: lateral condyle of the femur, greater trochanter of the hip, and the anterior superior iliac spine (representing the hip angle), in addition to the skin overlying spinous processes of T10, L2, L4, S2 (representing the upper and lower lumbar spinal angles). Subjects were asked to sit on a stool in the usual manner, with knees flexed at 90° in which usual sitting posture was assessed. No direction as to how to sit or an indication of what was being measured was provided. Subjects were then asked to sit in the slump sitting posture. Reliability of this form of measure has been previously established[33]. From this, the difference between usual and slump sitting was determined for the hip angle and upper and lower lumbar spinal angles.

4.3.4.3 Back Pain Beliefs

The Back Beliefs Questionnaire was used to measure the girls beliefs about back pain, in particular, with regard to movement avoidance. This questionnaire has been

found to be suitable for patients with LBP and also for workers with and without LBP[45, 46]. The questionnaire has 14 items with responses ranging from 1 (Completely Disagree) to 5 (Completely Agree). Scores range between 9 and 45 with five statements acting as distracters. Lower scores represent more negative beliefs of an individual toward low back trouble. Pilot data from Perich et al.[37] found the internal consistency for the Back Beliefs Questionnaire to be acceptable (Cronbach's alpha = 0.735).

4.3.4.4 Child Behaviour Checklist

The Child Behaviour Checklist Youth self-report form is designed to assess social competence and behaviour problems in children between 4-18 years. It consists of eight scales, consisting of 118 items that examine somatic complaints (eg. headaches, stomach ache), withdrawn behaviour, anxious/depressed behaviour, social problems (eg. making friends), thought problems, attention problems, delinquent behaviour and aggressive behaviour. Each item is scored on a 3-point scale ranging from "not true" to "often true". Two scores were calculated; firstly a "total problem" score (sum all items) and secondly, an age-standardised score (T-score mean (SD) of 50 (10)). T scores less than 60 are considered in the normal range, 60-63 represent borderline scores, and scores greater than 63 are considered as clinically important[2]. The questionnaire has been shown to be a reliable and valid tool[16]. A qualified psychologist based at the school of the INT group assessed all questionnaires.

4.3.5 Statistical Analysis

To determine whether differences in participant characteristics existed between the INT and CTRL groups at baseline independent t-tests were used. Two approaches were used for the analysis of primary outcome measures. Firstly, to determine whether differences existed for the incidence of LBP between the INT and CTRL groups, a χ^2 analysis was undertaken at each measurement period. A McNemar's test was also used to determine whether there were changes in LBP incidence over time data. Secondly, a χ^2 test was used to determine whether there were differences between sub-groups for the changes in the level of LBP and LBP-related disability (between Start-season and End-season). Also, an analysis of improvers and non-improvers within sub-groups (see results section for details) for subjects with LBP was undertaken for the INT and CTRL groups.

For all secondary outcome measures, paired t-tests were used to determine whether differences existed between Start-Season and End-Season measures for the INT group only. A McNemar's test was used to analyse if there was a significant change in subjects for the clinical classification (borderline clinical, clinical) on the Child Behaviour Checklist. All statistical analyses were undertaken using SPSSV16 for Windows (SPSS Inc., Chicago: USA) and the level of significance for all tests was set at $p<0.05$.

4.4 RESULTS

There were significant differences between the INT and CTRL groups for age, height and weight (Table 4.2). Higher levels of drop out were evident at Mid-Season and End-Season for the CTRL group when compared with the INT group (Figure 4.1).

4.4.1 Primary Outcome Variables

There were significant differences evident in the incidence of LBP between the CTRL and INT groups at Mid-season ($p=0.038$) and End-season ($p=0.042$) (Figure 4.2). Whilst the level of drop out was very high in the CTRL group the incidence of LBP in the cross-sectional group was similar to that observed amongst the schoolgirl rowers mid-season in the previous year[37].

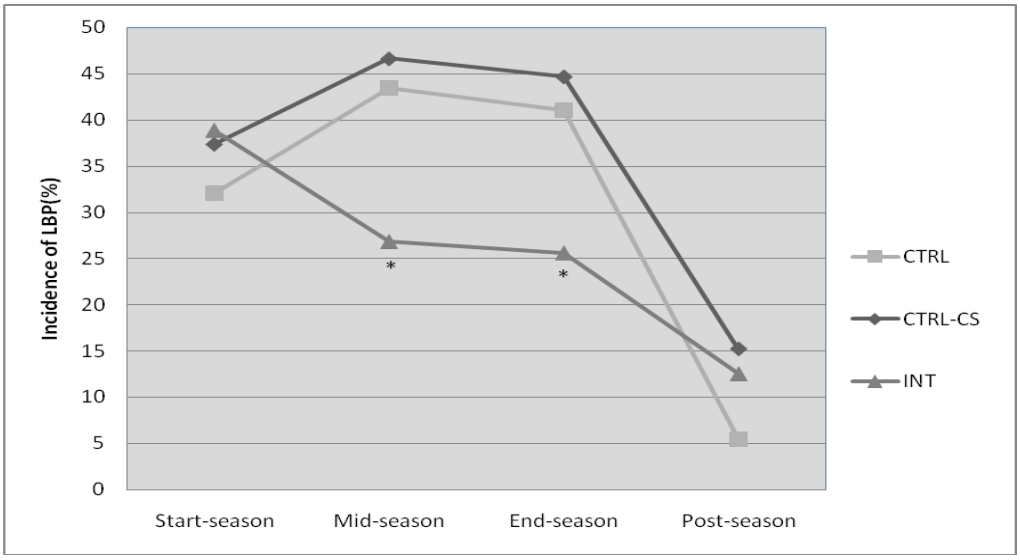


Figure 4.2: Incidence of low back pain (LBP) for INT (n=90) and CTRL (n=131) groups. The incidence of LBP at each testing session is also shown for the cross-sectional sample (CTRL-CS). * $P<0.05$ indicates a significant difference between the INT and CTRL groups

Table 4.2: Characteristics of the sample at baseline (start-season). Mean ± SD of data are displayed unless otherwise indicated.

Characteristic	INT Group (n=90)	CTRL Group (n=131)	p-value
Age (years)	14.7 ± 1.1	14.4 ± 0.9	0.027 *
Height (cms)	168.1 ± 7.2	165.4 ± 8.4	0.015 *
Weight (kg)	58.5 ± 10.3	55.6 ± 8.7	0.028 *
Incidence of LBP (%)	36.8	32.1	0.505
VAS (/10)	4.5 ± 1.4	3.8 ± 2.1	0.067
Oswestry (%)	7.8 ± 7.7	6.4 ± 6.3	0.400
Training hours			
On water	5.2 ± 1.7	5.6 ± 1.9	0.090
Off water	1.4 ± 0.7	1.3 ± 0.7	0.068

Note: * indicate a significant difference ($p<0.05$) between the groups at baseline.

VAS = Visual Analogue Scale

The mean change in the level of pain from Start-season to End-season improved for the rowers experiencing LBP in the INT group (1.2 ± 3.2) whilst it worsened for those in the CTRL group (-0.9 ± 2.9). This resulted in a significant difference (p=0.003) in the change in pain levels between the INT and CTRL groups. Whilst the mean change in disability score also lessened from Start-season to End-season for the INT group (1.5 ± 8.9) and worsened for the CTRL group (-0.7 ± 6.5) the difference was not significant between groups. A positive change in the improvement in VAS and Oswestry scores represents a decrease in score towards zero (no pain) and vice versa.

As mean data for rowers who experienced LBP was influenced by a zeroing effect for those who had no change in the level of pain, sub-group analysis was also undertaken. Rowers with LBP were classified into one of four groups in relation to the pain and disability scores. Table 4.3 show the proportion of ‘improvers’, ‘rowing pain’, ‘worse’ and ‘same’ subjects.

Table 4.3: Proportion of improvers and non-improvers in the INT and CTRL groups. Non-improvers were sub-classified (Rowing Pain, Worse, Same) according to pain and disability levels.

Sub-group *(Definition)*	**INT** **(N=37)**	**CTRL** **(N=41)**
Improve - Clear improvement of symptoms – no pain or disability at End-season or pain level = 2/10 at End-season	38%	17%
Rowing Pain – Reasonable levels of pain and minimal disability – indicated by a VAS = 3/10 and a disability score < 12% at End-season	27%	39%
Worse – Worsening of symptoms or maintained reasonable levels of pain and disability through the season - indicated by a VAS = 3/10 or a disability score = 12% at End-season	27%	12%
Same – Minimal symptoms of pain and disability and the symptoms remained essentially the same between the testing periods	8%	32%

Note: These descriptors were selected as 3/10 on the pain scale was considered to represent clinically significant pain and 12% as a disability score was considered to be clinically significant as it generally indicates that individuals have trouble sitting for an extended period of time or lifting.

There were significantly more rowers in the INT group with a clear improvement of symptoms from Start-season to End-season. Chi-square analysis showed that a significant difference (p=0.009) existed between the INT and CTRL groups for sub-groups (improvers and sub-groups of non-improvers) from Start-season to End-season. The INT group displayed a larger improvement in the change scores for both pain and disability from Start-season to End-season and also a larger decrease in these scores for the CTRL group for non-improvers (Figures 4.3a and 4.3b).

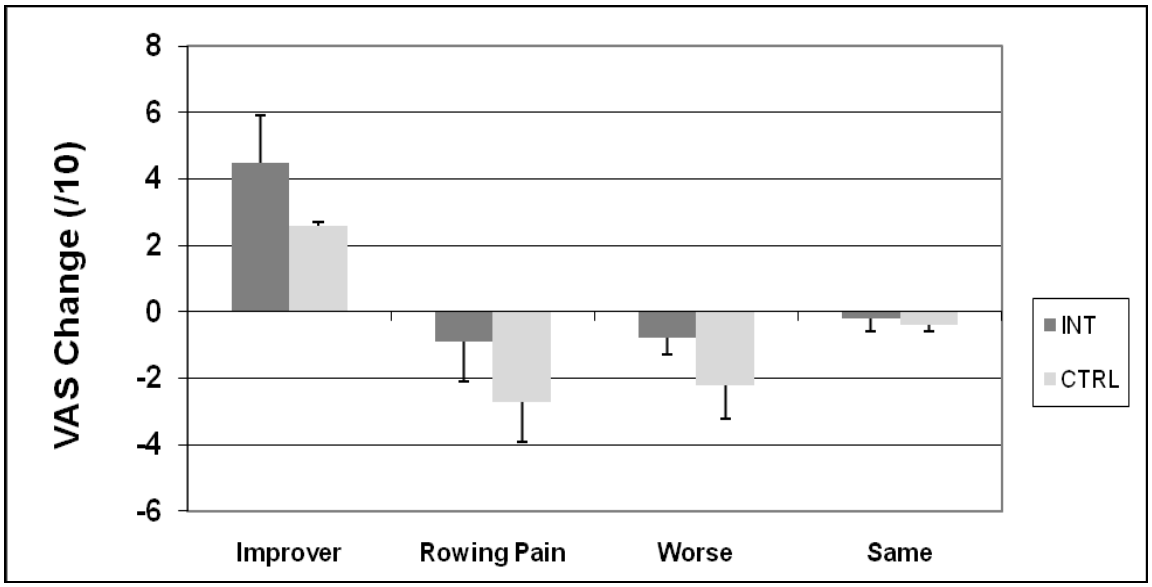


Figure 4.3a: Change in level of pain scores as determined by the visual analogue scale (VAS) from start-season to end-season for improvers and non-improvers (Rowing Pain, Worse/ Non-improvers and Same). Data are displayed as mean with error bars being standard deviations.

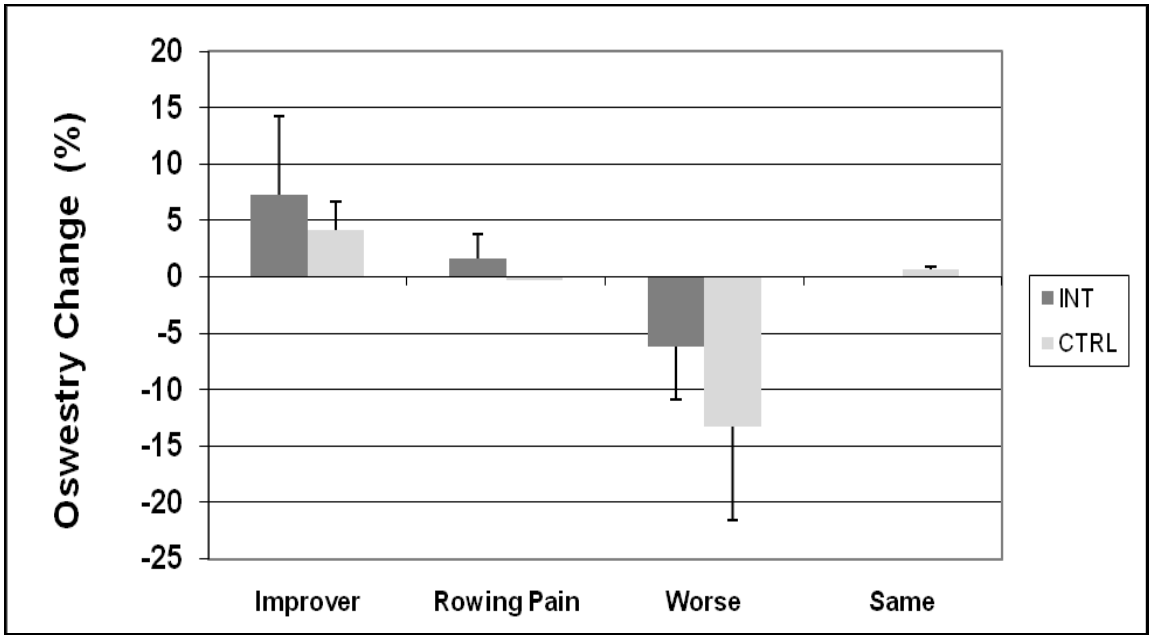


Figure 4.3b: Change in absolute level of disability scores as determined by the Oswestry Disability Index from start-season to end-season for improvers and non-improvers (Rowing Pain, Worse/ Non-improvers and Same). Data are displayed as mean with error bars being standard deviations.

4.4.2 Secondary Outcome Variables

Levels of physical fitness (lower limb endurance, back muscle endurance, 12 minute run, lumbo-pelvic flexibility) significantly improved ($p<0.001$) from Start-season to End-season, and girls sat significantly ($p<0.001$) further from end-range and displayed greater anterior tilt of the pelvis in the usual sitting posture indicating a more upright posture. Mean (SD) data have been provided in Appendix O (Table O.1).

The INT group showed positive changes ($p<0.001$) in child behaviour and this was evident in six of the eight scales of the Child Behaviour Checklist. Furthermore, there were significant decreases in the number of rowers classified as borderline clinically at risk ($p=0.002$) and clinically at risk ($p=0.016$) from Start-season to End-season when the total score was considered. These Child Behaviour Checklist data are also provided in Appendix O (Figure O.1, Table O.2).

Back pain beliefs were positive and no changes for the INT group were evident in this study (Start-season 31.8 ± 3.8: End-season 32.5 ± 5.3, $p=0.178$).

4.5 DISCUSSION

The most important finding of the current study was the multi-dimensional program utilised which involved physiotherapy education, screening and individualised "specific" exercise intervention, combined with off-water strength and conditioning sessions led to a decrease in the incidence of LBP and the levels of pain and disability when compared with the CTRL group. The intervention program adopted in this study was based upon an Academy/Institute of Sport model within which athletes undertake musculoskeletal screening prior to being exposed to a sudden increase in training load. This commonly occurs in talent identification and higher level athletic programs, but not in schools.

The incidence of LBP for the INT group was significantly reduced during the rowing season when compared with Start-season and when compared with the CTRL group. In addition, when those experiencing LBP at the beginning of the season were sub-classified into improvers and non-improvers, the INT group showed more improvement in pain and disability scores. Whilst an advantage of this study is the multi-dimensional approach to injury prevention[1] within which impairments specific to the individual, education, reduced on water training and conditioning were factors targeted in the program, the nature of the approach makes it difficult to determine the exact mechanism/s for the improvement in LBP-related markers. However, recent research that instituted this program, while controlling for the training and conditioning aspects, revealed that the physiotherapy and educational aspects of the program were efficacious in reducing the incidence of LBP in adolescent schoolgirl rowers[47]. On this basis it can be speculated that modifiable personal factors that are targeted by the education and physiotherapy components of the intervention (cognitive functional movement training) across the bio-psycho-social domain appear to be associated with LBP in this population.

Physical fitness (aerobic conditioning, lower limb and back muscle endurance and sit and reach flexibility) in addition to seated posture (usual and slumped sitting) were all improved in the INT group. Previous research has identified that reduced lower limb and back muscle endurance and seated posture were associated with LBP in schoolgirl rowers[37], and reduced lower limb endurance has been identified as a physical characteristic existing prior to low back injury[43, 48]. This could be an important factor for rowing because if the legs are prematurely fatigued and thus complete the extension too early, and/or are unable to produce pre-requisite force levels, the rower's back may

then be the main contributor in producing force on the oar. Further, reduced back muscle endurance may render the spine vulnerable to increased tissue strain by failing to control bending forces[29, 32].

Rowers spend many hours training and competing in a seated posture whilst the thoracolumbar spine moves through a variety of flexed and rotated postures. Spinal posture education in sitting, squatting and lifting was translated in to rowing specific functional exercises which translated in the INT group rowers in changing the usual sitting posture (sitting further from the end range). It has been reported that upright sitting is associated with increased back muscle activation, and is correlated with improved back muscle endurance[31-33]. It is also known that sitting posture correlates with bending and lifting posture[28] which may have had a carryover also to rowing posture. Making rowers aware of the end range flexion in conjunction with improved endurance of the back and lower limb muscles may have contributed towards reducing the flexion strain of the low back and decreasing the incidence of LBP and consequently the levels of pain/disability in this cohort.

Psycho-social problems have been linked to the development and the presence of adolescent back pain[39]. The most commonly identified aspects of psychological distress are depression and anxiety, and there is some evidence that high levels of psychological distress are predictive of future LBP episodes[13]. Despite not collecting the control data for child behaviour, the significant improvement from Start-season to End-season in Child Behaviour data as a whole in the INT group, and particularly the significant reduction in the number of rowers who were classified in the clinical or borderline clinical range is a positive result of this program both in terms of the general well-being of the rower and possibly, the risk of future LBP. Previous studies involving exercise and psycho-social markers have shown substantial associations between the regular practice of sports and psychological wellbeing[23, 36]. It may be that the promotion of physical fitness and performance, participating in a team with peers, the individual attention and the feedback from the physiotherapists combine to provide positive social feedback and recognition and subsequently to these improvements.

There are limitations of this study that need to be acknowledged. Firstly, the study sample was not randomised, however this was difficult to do in the sporting/school situation. Secondly, the exact component(s) of the program that contributed to improved primary outcome data could not be determined. Thirdly, the

improvement in secondary outcome variables for the INT group were not measured in the CTRL group for logistical reasons which did not allow for controlling for effect of participating in a row program. Fourthly, there was a large dropout in the CTRL group limiting the findings. However, the incidence of LBP followed a similar pattern to the cross-sectional sample obtained in this study and was also observed in data collected in a scoping study in the previous season[37]. Fifthly, the follow up time for the data collection was 12 weeks, and hence it is not known whether the results would be the same if the follow up time was a number of years. The intervention program has continued to run in subsequent seasons due to anecdotal reports of successful outcomes and support from school management, however, formal tracking of primary outcome data has not been undertaken. Finally, the aim of any training program should be to enhance athlete performance whilst preventing injury. In the 2006 rowing season, the INT group was dominant in the schoolgirls rowing competition after a less successful season in 2005. Whilst anecdotal reports from the coaches from the INT school were that the rowers were able to produce an increase in training intensity during training sessions in comparisons to previous seasons, this factor was not measured.

Subsequently, this research has changed the practice in the rowing program in the school that participated in the intervention. Land training with a focus on aerobic conditioning and back and leg muscle endurance has been introduced as pre-season conditioning with water training not commencing until later in the season. An education session is provided for all rowers, parents and coaches before the season commences. Individual musculoskeletal screening and targeted exercise training by a physiotherapist trained in this approach is now offered to all new rowers to the program with follow up screenings for all rowers. Ergometer training time and on-water training times are restricted and there is the continual education of rowers, coaches and parents. The efficacy of the various components of the intervention are currently being examined to determine whether certain elements are more responsible for the reduction in LBP.

4.6 CONCLUSION

It can be concluded that rowers have a high incidence of LBP, but multi-dimensional intervention can be implemented to decrease the pain and disability amongst this cohort. Further research is needed to determine the respective long-term results with regard to back pain. Prevention of these injuries requires increased knowledge among health care

professionals, athletes themselves, trainers, coaches and parents as rowing is a sport with high demands on the spine.

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CHAPTER 5 – DISCUSSION AND CONCLUSIONS

5.1 INTRODUCTION

As stated in Section 1.7 of thesis, rowing is available for girls in Years 9 – 12 (14 – 17 years of age) at the IGSSA schools in Western Australia. It is one of the most popular participant sports on the IGSSA Calender and it consumes a large percentage of each school's sporting budget. The IGSSA rowing program is conducted over the winter months with five regattas being held between May and August each year. Rowing is viewed as an important and unique competitive sport in the IGSSA sporting program for two reasons. Firstly, whilst it attracts girls of high sporting ability it also attracts girls who don't typically compete in other co-curricular sports. Secondly, in a majority of cases the participants have a limited background in the sport itself. It is also notable that the parental involvement is high, and it is a sport in which many fathers are involved with their daughters. Therefore, the health and social benefits of the sport are many.

In 1999, the decision was made by the Principals of the IGSSA schools to replace sweep four races with quadruple sculls as it was thought that the twisting action in sweep rowing[46] may be exposing the girls to a greater risk of injury. These opinions of rowing being a sport that has a high rate of LBP has been reflected in the literature, with clinical evidence and previous research suggesting that LBP is common in rowers[5, 23, 24, 45, 54, 56, 61]. Discussions between the Principals continued on what was best practice for the students (with the contention that girls were still allowed to row in sweep eight events) and the reluctance for change was voiced by the rowing co-ordinators of the IGSSA schools. It was the lack of related research on schoolgirl rowers, and the desire for the Principals' of the IGSSA schools to formulate policies relating to duty of care, that stimulated this doctoral research.

As the aetiology of LBP is known to be multi-factorial[2, 30] (Figure 1.3), a bio-psycho-social model of LBP[40, 59] was used as the theoretical framework for this thesis. Whilst the majority of research conducted in rowing to date, has been based upon cohorts of the elite and adult or collegiate rowers[23, 53, 56, 61], there is a lack of research that has been conducted on adolescent female rowers regarding: the prevalence of LBP; the factors associated with LBP; and the interventions aimed to decrease the prevalence of LBP.

5.2 SUMMARY AND DISCUSSION OF MAIN FINDINGS

The overarching aim of this thesis was to examine various aspects of LBP amongst the Schoolgirl rowing population in Western Australia. More specifically, three studies were conducted to: 1) determine the extent and nature of the LBP problem; 2) determine variables from the bio-psycho-social domain that are associated with LBP in this group; and 3) to intervene to attempt to reduce the extent and severity of the problem (Figure 1.3). These studies are summarised and the main findings are discussed below.

5.2.1 Study I – An Examination of Low Back Pain in Adolescent Schoolgirl Rowers

The general aims of the first study of the thesis were to determine the incidence of LBP in schoolgirl rowers and to examine the self-reported factors that are associated with the initial onset of LBP, or exacerbate pre-existing LBP. To this end, 356 participants from six IGSSA schools (approximately 72% of the total IGSSA rowing cohort) were recruited as the experimental group in this study. A matched control group of 496 IGSSA schoolgirls who did not row was also recruited.

An important finding of Study I was that there was a high incidence of LBP in schoolgirl rowers within the schoolgirl rowing cohort as demonstrated by the LBP point prevalence of 47.5%. This was significantly higher when compared with the point prevalence of 15.5% for the control group. These findings support the fact that the incidence of LBP in schoolgirl rowers is high, even when compared with older and more experienced rowers[23, 24, 52, 53, 56, 61]. Whilst the overall LBP statistics were of concern, there was also an interesting finding when LBP incidence was considered per year group. The point prevalence of LBP at the Year 9 level (the first possible year of being involved in the rowing program) was significantly greater than that reported for the Year 10 level (Figure 5.1). This differs to what is suggested in the literature, that is; that there is a progressive increase in LBP incidence with age during adolescence[4, 22, 47, 48]. The increased incidence of LBP at the Year 9 level when compared with the Year 10 level may be attributed to coaches attempting to fast-track the technical skills of beginning rowers without the young rower's body being sufficiently prepared. Also, as previously mentioned in Section 5.1, rowing attracts many girls who have not participated in sporting pursuits outside of the normal curricular sporting programs therefore, they have not received the cross training effect of being involved in other co-

curricular sports. Anecdotal evidence from the rowing coaches and physical education staff at the IGSSA schools suggests there is a reasonably high drop-out rate for students in the rowing program between Years 9 and 10. This has often been attributed to either a mismatch between rowing-related workload and athlete maturity (ie. they find the sport too demanding), or to girls just wanting to try the new activity that is offered and deciding rowing is not for them. However, the drop out rate may have also been due to the girls developing LBP as it has been hypothesised that there is relationship between low physical activity levels and LBP[7]. A recent review by Maffulli and associates[29] does however highlight that little is known about the extent to which injury causes young athletes to withdraw from sports participation. Further research on this cohort would be required to confirm that firstly, the drop out rate exists and secondly, if this is confirmed whether LBP is a reason for decreased physical activity.

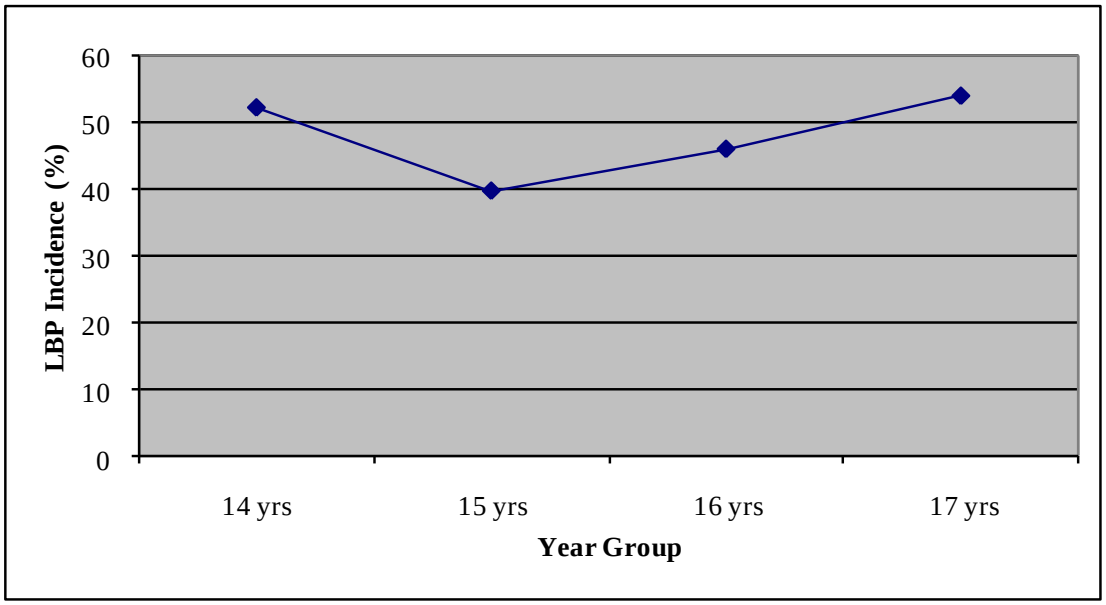

Figure 5.1 Age effect of incidence of LBP found amongst rowers in Study I

Previous studies investigating the prevalence of LBP amongst rowers have not reported the levels of LBP and disability. However, this may be due to the fact that most of the studies reported in Table 1.1[23, 24, 52, 53, 56, 61] were conducted on high-level athletes who are known to compete and train with musculoskeletal pain anyway. With the goals of the IGSSA rowing competition being both participation and competition, it was considered important to examine both the levels of LBP and disability amongst this group of schoolgirl rowers. In Study I, rowers reporting LBP, when all age groups were pooled, showed significantly greater levels of pain and disability than the non-rowers.

However, when average scores are considered the levels of LBP reported by rowers in this study would be considered "moderate"[8] and the disability levels would be considered "low"[13]. However, a large percentage (28.4%) displayed clinically significant disability scores. Also of interest are the findings of a recent study by Fritz and Clifford[15] who found that adolescents with LBP as a result of sports participation tended to have lower baseline disability scores and experience less improvement in disability with outpatient physical therapy treatment than did non participants in sports. These authors concluded that additional research is needed to identify the risk factors for recurrence or delayed recovery, and to clarify optimal management strategies for LBP in adolescents.

The participants in this study reported many factors that provoked, or exacerbated the LBP with long rows in training sessions, lifting the rowing shell, rowing in a sweep eight and ergometer training being reported most commonly. These factors should therefore, be considered in future LBP intervention programs in rowing. For example, with education of coaches and rowers and restrictions on the duration on training times, it may be possible to assist in decreasing the levels of pain and disability in rowers. Also, by restricting training times on-water and on rowing ergometers, this would decrease the duration of sitting and also the mechanical load transferred to the low back, which may also contribute to decreasing the extent of LBP in this group. Restricting the training time on rowing ergometers has been suggested by other authors who have found a link between training time on ergometers and LBP in elite rowers[56, 61].

The most commonly cited reasons for LBP affecting everyday function in rowers were lifting, sitting and standing. Positive[19, 50] and negative[26, 33] associations have previously been found with carrying schoolbags, whilst sitting at school has been rated highly on scales of disability in adolescents with LBP[60]. In a similar vein to rowing-related factors, these habitual factors of lifting, sitting and standing could be addressed in LBP prevention programs in rowers, but also for life outside of rowing.

The majority of rowing training was completed in sweep boats and rowing-related training hours increased with age, peaking at an average of 9.2 hours per week at the senior (16-17 years) level. Approximately, two-thirds of the rowers indicated that they spent less than five hours per week with other sporting interests showing that during the rowing season most rowers chose only to row. It is a positive attribute of the

IGSSA rowing program that it attracts girls who potentially would be participating in no other sporting activities, however, it is important to minimise the risk of injury by identifying possible risk factors and adequately preparing the young and developing bodies for the sport. Not only may experiencing LBP deter them from continuing with rowing as a fitness pursuit, but it may also be detrimental to the long term spinal health.

5.2.2 Study II – Factors Associated with Low Back Pain and Classification of Motor Control Impairments in Adolescent Female Rowers

With the confirmation of a high prevalence of LBP amongst the rowers from Study I, the need to investigate the differences between rowers with and without LBP was highlighted. From the large rowing cohort recruited in Study I, a sub-cohort for the second study of the thesis was recruited near the end of the same rowing season. Specifically, schoolgirl rowers with levels of pain > 3/10 and disability levels > 12% (LBP group, N=30) and those without LBP (N=30) were recruited for Study II. In the general LBP literature, LBP is believed to be a multi-factorial problem with risk factors coming from the bio-psycho-social domain[40, 59]. Therefore, the aim of the second study of this doctoral investigation was to determine the physical and psycho-social variables associated with LBP in schoolgirls rowers and to describe the patterns of motor control impairment present in those with LBP.

In the two to three weeks prior to the completion of the rowing season (so data collection did not interfere with the rowers preparation for the premier event of the year (the Head of the River regatta)), 60 rowers recruited for this study attended the School of Physiotherapy at Curtin University to complete pain and disability questionnaires, questionnaires investigating psycho-social factors, a physical activity questionnaire in addition to a battery of physical tests. After the conclusion of the season, the 30 rowers with LBP were invited for a musculoskeletal examination of which 23 consented.

From the musculoskeletal examination, it was found that the majority (N=19) of the rowers who experienced LBP were classified with either a flexion or multi-directional control impairment. This finding is of relevance to the pathomechanics of LBP as rowing involves the repetitive flexion/extension of the lumbar spine[35]. This finding was also consistent with Ng and associates[34] who found that rowers with LBP spent a greater proportion of the rowing stroke in flexion when compared with rowers without LBP during the drive phase of ergometer rowing. Rowers with flexion and

multi-directional control impairments all reported experiencing pain in flexion related postures and functional activities[36] such as forward bending, cycling and rowing. It is proposed that this functional loss of motor control into flexion results in flexion strain and pain[36, 37]. Individualised "specific" exercise programs to address these deficits in motor control were considered to be of value in this group of rowers and were a key component of the intervention program conducted in Study III.

In the cross-sectional arm of Study II there were many findings of interest. LBP subjects reported that the pain whilst rowing in the week prior to testing was higher than the pain at the time of testing, and they had disability scores that would be considered as clinically significant.

Whilst no difference was found in levels of physical activity between the LBP and no-LBP groups, physical testing revealed deficits in the LBP group for both lower limb endurance and back muscle endurance. This supports other evidence that exists linking adolescent LBP with deficits in trunk[28, 49] and lower limb muscle endurance[3]. It is not known why deficits in muscle endurance were present in the pain group given that they were as active. Previous research has identified that deficits in back muscle endurance are related to many factors including: increased height, reduced body mass index, slumped sitting spinal posture, sedentary activity (time sitting), physical activity, self efficacy, pressure pain thresholds and genetics[18, 51]. However, these physical deficits are considered important for rowing performance as outlined in Section 3.4 of the thesis. It can be speculated that if the legs are prematurely fatigued that the rower's back may become the main contributor to produce force on the oar and that poor back muscle endurance may render the spine vulnerable to increased tissue strain by staying for a longer duration with a flexion load.

Clear differences in sitting posture were not displayed between groups which was an unexpected finding, as it was predicted that those with LBP would sit more slumped (closer to the end range flexion) when in the usual sitting posture. This finding was in contrast with Astfalck and associates[3] who examined adolescents with LBP and studies that have investigated adults[10, 38]. These studies have found that when LBP subjects are sub-classified, statistically significant and clinically meaningful differences are evident for lumbar angles during usual sitting. The absence of sitting-posture related findings in this study may have been due to pain subjects being; firstly, more aware of sitting upright due to the fact that they were being tested or secondly, that the usual

sitting posture did not accurately reflect the spinal posture when undertaking a dynamic task such as rowing.

Differences in spinal repositioning ability were evident when the regions of the lumbar spine were examined, with greater variability in repositioning ability being identified for the upper lumbar spine for rowers with LBP. This supports findings from other studies that have demonstrated spine repositioning deficits in patients with LBP[6, 39, 55]. These findings also highlight the importance of examining regional differences of the spine[31], as the greater variability in repositioning error identified in the back pain groups for the upper lumbar spine in this study may represent a vulnerability of the lumbar spine to tissue strain. Rowing is a sport in which the body is loaded from the feet up, as well as from the top down, and hence demands control across both the upper and lower lumbar spine. It may be hypothesised that deficiencies in spinal repositioning sense may put rowers at risk of LBP as they may be more likely to unknowingly position the spine at end-range in the process of the execution of the rowing stroke, exposing them to increased risk of tissue strain.

LBP participants who displayed flexion or multi-directional control deficits displayed an increase in generalised joint hypermobility when compared with those with no-LBP. Fritz and associates[16] found greater ligamentous laxity as measured by the Beighton scale in patients with lumbar segmental instability (as determined by both a radiographic and clinical examination), supporting that a relationship may exist between generalised joint hypermobility and spinal mobility. However, other studies have shown no evidence that individuals with generalised hypermobility are at greater risk of developing LBP[20, 44]. The finding of an increase in hypermobility in the sub-classified LBP rowers may highlight that rowers with hypermobility are at greater risk of developing LBP under mechanical load. This may be consistent with a previous review that reported that generalised joint laxity may reflect a deficit in the spine's passive stabilising structures to transmit loads effectively[17].

Whilst the importance of hamstring flexibility has previously been outlined[43], there were technical problems with the collection of the data for the long sitting forward reach flexibility test and these results were not able to be analysed.

From the results of the Child Behaviour Checklist it was revealed that there was a greater proportion of rowers with LBP who were clinically classified as either borderline-at risk or, at risk, however, cell sizes were too small to perform statistical

analyses. These proportions were amplified in the LBP participants sub-classified with flexion or multi-directional control disorders. Previous research has suggested that pain is commonly accompanied by emotional arousal and distress[42] and this may raise the awareness of bodily sensations, increase the severity of pain, and lower pain tolerance[59]. In addition, it is known that psychological distress (with the most common aspects being depression and anxiety), has the capacity to alter motor control parameters across the spine as well as lower pain thresholds[27], and there is some evidence that some aspects of psychological distress are predictive of future episodes of LBP[14]. Awareness of psychological factors and attempting to decrease the effect may play a role in decreasing the prevalence of LBP and future prospective studies will be required to investigate this.

The results of Study II combined with the scoping data of Study I identified potential risk factors that are possibly modifiable amongst the adolescent Schoolgirl rowing cohort. The specific findings of deficits in back muscle endurance, lower limb endurance and repositioning sense highlighted potentially modifiable risk factors that could be targeted in an intervention program. This provided some evidence to create an informed multi-dimensional intervention strategy aimed at decreasing the LBP prevalence in Study III.

5.2.3 Study III – Low Back Pain in Adolescent Female Rowers: A Multi-dimensional Intervention Study

The aim of the final study of this thesis was to determine whether a multi-dimensional intervention program was effective in reducing the incidence of LBP and related pain and disability levels in Schoolgirl rowers. This study was a non-randomised controlled trial with schoolgirl rowers from one school forming the experimental group and rowers from three other schools forming the control group. The intervention program consisted of an individualised "specific exercise" program based on an individual musculoskeletal screening, a LBP education session conducted by a physiotherapist and an off-water conditioning program. Other restraints on the experimental group included; the total training hours were not altered from the previous season and ergometer training was not to exceed 30 minutes duration in each session. Strength and conditioning sessions were scheduled with weekend on-water sessions and ergometer training to restrict coaches from exceeding the training time constraints.

Participants in the control group did not receive any advice regarding changing training practices, however, for ethical reasons head coaches of the respective programs and Principals from the IGSSA schools were informed of the results of Studies I and II. Further, they were also informed of the changes that the intervention school was intending to make for the subsequent season which formed this study. The changes that were outlined to Principals and coaches from the schools involved in the control group included:

- the intervention school would introduce land training in Term One to form pre-season conditioning;
- water training was to commence later in the season once the adolescent bodies had been prepared;
- musculoskeletal screening offered to all rowers and given to all new rowers to the program;
- follow up screening sessions for all those who had an original screen to monitor and progress the rower;
- ergometer training and water training would be restricted in duration to 30 minutes on the ergometer and 90 minutes per session on the water, and in addition the total training time for the rowers would not increase from the previous season.

At the conclusion of the season that the intervention was conducted, the rowing co-ordinators from the schools forming the control group, revealed they had made some changes to the training practices based on the information that was given to them at the start of the season. These changes included; adding wheels to coaches chase dinghies so that rowers were not required to carry the load as far, through the pre-season and the competitive season pilates and aerobics sessions were implemented to supplement the water training, and one school indicated that they increased the focus on core stability and leg strength during off-water training sessions.

The most important finding of this study was that the multi-dimensional intervention program utilised led to a decrease in the incidence of LBP (Figure 4.2) and the levels of pain and disability (Figure 4.3a, b). It can be seen that whilst there was a large drop-out rate in the control group, cross-sectional statistics revealed the same

pattern of LBP incidence (Figure 4.2). The significant improvements found in one of the primary outcome variables in this study (LBP incidence) were predominantly better than those found in other intervention approaches of core strengthening[9, 32, 58] and specific exercise[21, 25] to reduce LBP in sport (Table 5.1). However, direct comparisons are difficult to make as many of the interventions differed in nature (exercise type, intervention period), were performed on different sporting populations of different performance level (therefore related mechanical loading would vary), and had varying proportions of participants entering these studies with pre-existing LBP. Therefore, it is not surprising that variable changes in primary outcome variables have been found.

Further, there were improvements found in the levels of pain and LBP-related disability. In this study, the incidence of LBP decreased for the rowers in the intervention program when the training load was applied, whilst the incidence increased amongst the rowers at the control schools. The combination of the change in nature of the training sessions, with greater work on land and less on water (no change in total hours from the previous season), the musculoskeletal screenings and individualised specific programs addressing deficits in sitting, lifting, bending and rowing techniques and posture and movement control, and education combined to produce positive outcomes for the rowers. This study differed from other LBP intervention programs in that it addressed several factors rather than a single, and generic intervention.

Several of the secondary outcome variables measured in this study also improved from the start of the season to the end of the season for the intervention group. These variables included improved physical fitness and conditioning (aerobic conditioning, lower limb and back muscle endurance), more upright seated posture (usual versus slump sitting) and improved psycho-social variables as measured by the Child Behaviour Checklist. As the control group was also participating in a rowing program it must be acknowledged that improvements in these outcomes measures may have also been as a result of participating in the rowing season rather than being solely due to intervention.

Despite Study II showing a lack of psycho-social findings and that few differences were found between sitting postures for rowers with and without LBP, the differences observed in these variables in Study III may have been for the following reasons. For the psycho-social data, Study II involved a cross-sectional design with LBP and no-LBP groups (N=30) being compared whilst Study III was a repeated-measures design with a

Table 5.1 Details of intervention studies that have examined low back pain (LBP) / back injuries in sport

Author(s)	Nature of Intervention/Participant Details	Back Pain Related Outcome Measures	Intervention Period/Follow-Up Period(s)	Results and Conclusions	Comments
Koutedakis et al (1997)[25]	Specific exercise – hamstring strengthening. N=22 Female rowers. No control group recruited. 5.6±3.3 days of action due to LBP at baseline. 52% of female rowers experienced LBP at baseline.	• History of back injury 12 month prior to testing. • Training and competition days missed due to LBP.	6-8 months and no follow up.	• Training days missed due to LBP significantly reduced to 3.1±2.2 days. Hamstring strengthening contributed to a reduction in LBP.	
Cusi et al (2001)[9]	Evaluate relationship between LBP and groin injury and an exercise intervention program for trunk strength. N=39 Male rugby players (N=19 in control group, N=20 in intervention group). Groups were randomly assigned. One subject with LBP history. Both groups underwent a standard fitness and stretching program. Intervention group carried out three additional exercises on a Swiss ball twice weekly (10-15 mins).	• Injury incidence evaluated pre-, mid- and end-of-season. • Flexibility and back strength were assessed pre-, mid- and end-of-season.	10 weeks and no follow up.	• Fewer lower back and/or groin injuries in the intervention group over the course of the rugby season, however these differences did not achieve statistical significance (5 injuries in intervention group, 7 injuries in control group) • No statistically significant differences in LBP prevalence or in flexibility and back strength between groups.	Sports specific risk factors for athletes participating in rugby union were not identified. Results limited by a small sample size and a small number of injuries. Exercises were delivered to intervention group as a whole and not based on individual differences
Nadler et al (2002)[32]	Core strengthening program on LBP occurrence and hip strength differences were studies in NCAA Division 1 collegiate athletes. 30-45 min core strengthening program performed 4-5 times per week pre-season, 2-3 times per week during the season. N=164 pre-intervention, N=236 with intervention	• Hip strength over consecutive years • Occurrence of LBP by recording athletes requiring treatment monitored throughout the year	12 months and no follow up.	• No significant advantage of core strengthening in reducing LBP occurrence, though this may be a reflection of the small numbers of subjects who actually required treatment. • 8.5% required treatment prior to intervention, 6% required treatment with intervention.	The core program seemed to have had a role in modifying hip extensor strength balance.
Harringe et al (2007)[21]	Specific segmental muscle control exercise instituted by a physiotherapist with female gymnastics team (aged 11-16 years). Carried out to the entire group, at the same time. N=42 (Intervention group N=30 (15 with LBP), Control group N=12 (4 with LBP).	• LBP prevalence • Number of days with LBP • Intensity of pain measured with Borg's category-ratio scale.	12 weeks and no follow up.	• Eight gymnasts out of 15 with LBP in the intervention group became pain free • Intervention group displayed a significant reduction of days with LBP and reduced pain intensity compared with gymnasts in the control group. • No significant difference in terms of maximal as well as median intensity of pain within the groups was detected Specific segmental muscle control exercises of the lumbar spine may be of value in preventing and reducing LBP in gymnasts.	Individual differences not taken into account in applying program. 47% reported LBP at baseline. One gymnast in the intervention group and two gymnasts in the control sustained LBP during the study.

larger sample being tested. In addition to the actual differences in effect size, these differences in study design and sample numbers may have led to differences in experimental power. The changes in sitting posture were likely to be due to the abovementioned differences in experimental power, as well as the education and the specific exercise components of the intervention. Sitting posture was also measured in the school environment to which the rower was familiar in Study III rather than a laboratory environment as in Study II. In addition, the rower worked with the physiotherapist with whom they were familiar, creating a relaxed rather than a more formal testing environment.

As stated above, the multi-dimensional intervention program utilised in this study led to improvements in the primary and secondary outcome measures. As LBP is known to be a multi-faceted problem it is likely that these positive findings were due to improvements in a number of factors. Specifically, the rowers in the experimental group may have been better prepared for rowing as a result of the individual specific exercises prescribed from the musculoskeletal screenings, improvements in lower limb and back muscle endurance and the restriction on training durations in the boats and on the rowing ergometers. The intervention approach adopted in this study lends support to a recent systematic review[1] which examined the effectiveness of injury prevention programs in adolescent sport. These authors concluded that multi-faceted interventions that consider pre-season conditioning, functional training, education, proprioceptive training and sport specific skills which are continued throughout the season are warranted. Determining whether any of these factors was of greater importance may be of interest in optimising program design. Finally, by participating in the intervention program, the rowers had contact with more people (ie. the physiotherapist, the strength and conditioning coach) with whom they were able to develop individual relationships and who took an interest in the individual well-being and progress. The benefits of such relationships to adolescents should not be negated. The results of this study suggest that a multi-dimensional program of this nature should be at least considered by schools or rowing clubs within which adolescent females form the rowing program. There is also potential to apply this model of management of LBP to other rowing populations as well as other sporting populations

There are a number of points that need to be considered to replicate the findings of this study. Firstly, the intervention program was facilitated by financial support from the school participating in the intervention and this assisted in addressing the related

financial commitments. Secondly, the PhD candidate and physiotherapists regularly attended training sessions and were thus visible to the rowers, parents and the coaches and it was considered that this assisted in creating an environment in which everyone was working towards the same goals of producing conditioned, educated and high performing schoolgirl rowers. Finally, a key feature of this study was that coaches, rowers, parents and physical education staff were all educated on the approach used in this study and this may have encouraged the high adherence levels to the program (>90% as measured by training attendance).

A potential barrier for future use of the intervention approach used in Study III is the use and cost of the physiotherapy component of the intervention in large groups of rowers. It is also not known whether rowers maintain the skills and knowledge related to the intervention in future seasons as there may be a carryover effect of motor memory and education. Another potential confounding factor is that those without LBP may question undertaking a program in future seasons as the lack of symptoms may decrease adherence[41]. However, the results of this study show that there is merit in those without LBP participating in the intervention as there were less reports of LBP as the season progressed for the intervention group. Finally, although there is a time-cost associated with organising a large intervention program such as that outlined in this study, there seems to be merit in performing such an intervention for the overall well-being of the athlete.

5.3 PRACTICAL IMPLICATIONS OF THE RESEARCH

As there has been limited research examining the epidemiology of LBP in schoolgirl rowers and the fact that there have been no studies which have examined risk factors in adolescence this doctoral thesis was clearly a novel investigation. This research has identified modifiable risk factors that has led to targeted management and treatment specific to the disorder presentation and identified impairments. The aim of multi-disciplinary sports injury research, as conducted in this thesis, is to inform practice. The rowing co-ordinators from IGSSA schools have now been provided with valuable information to formulate policy.

Based on the findings of Study I in which rowers generally experienced LBP in the boat that they trained in (sweep or scull), as opposed to solely in sweep boats, School Principals opted to maintain sweep rowing in eights as part of the regular

regatta program at all age levels with the First Eight race being maintained as the premier event on the program. This decision was well accepted by the rowers and rowing co-ordinators as the sweep eight is generally considered as the preferred event of the rowers. In addition, Principals encouraged the rowing co-ordinators to adapt the programs and made the findings of all studies contained within this thesis available to rowing coaches and co-ordinators from all schools involved in rowing in Western Australia. Whilst this research was conducted on schoolgirls only, rowing co-ordinators from the Schoolboys rowing programs were also informed of the findings from this research. Furthermore, the health benefits of the rowing programs were clearly shown to the Principals, not only with the rowers displaying improvements in the physical health from the start of the season to the end of the season, but also the improvements in mental health were outlined. This is a positive finding when considering that large financial costs are attributed to rowing programs.

This research changed the way the rowing program is run in the school that participated in the intervention program, by adopting the components of the intervention program of Study III as general practice. The belief in the value of the program extended not only to the rowers, coaches and the parents, but also to the Parent Support Group. This group now subsidises the costs involved for the musculoskeletal screenings to all new rowers to the program. The noticeable performance improvement of the intervention school in regattas, although not a goal of the intervention, enhanced the positive belief of onlookers on the program. Coaches at the intervention school subjectively indicated that the rowers were able to manage a higher workload than the previous season and in turn produced outstanding results with the team winning the aggregate points trophy for the Head of the River regatta. Finally, whilst this study highlighted that a well constructed treatment program can reduce the incidence of LBP in this group of rowers, it would also make sense to examine rowing technique and monitor training load in the future. This intervention approach targeting potential risk factors and screening athletes prior to the involvement in sporting pursuits, may be expanded to other seated sports (eg. kayaking, cycling) and other sports that carry a high risk of LBP (eg. gymnastics).

5.4 SPECIFIC LIMITATIONS OF THE DOCTORAL INVESTIGATION

Whilst general limitations of the thesis were outlined in Section 1.6, there are some specific limitations that should be outlined.

Firstly, the findings of this research are gender, age and ability level specific, therefore, generalisation of the findings to all rowers should be made with caution. The LBP incidence data collected in Study I was collected at one point in the season only (mid-season) and it is known (from Study III) that LBP incidence fluctuates throughout the season. Furthermore, the cross-sectional design of Study II cannot determine cause and effect and the relatively small number of participants may increase the chance of error in statistical tests. In addition, with the classification of subjects with the movement control impairment, there was a lack of measures to validate the classification, although previous studies have supported the validity and reliability of this clinical method[10-12]. With the selection of subjects for the collection of cross-sectional data, bias, particularly in the psycho-social status of the subjects may have arisen, as schools made only the easiest to manage students available despite the sport of rowing attracting a range of students and often those who find it difficult to find the niche within the school. This is a natural thing for staff within a school to do when outsiders are directly dealing with their students and this was not controlled for in this study. It may explain why more at-risk students were identified as part of the intervention of Study III in which almost an entire school rowing cohort was involved.

In the final study the sample was not randomised, however this is difficult to achieve in a school sporting environment. Study III was conducted in the field so whilst it has high ecological validity, in some instances, strict experimental control was not possible. In addition, secondary outcome data was collected for the intervention group only for logistical reasons, which did not allow for the effect of participating in a seasonal rowing program. The follow-up time for data collection for the intervention program was 12 weeks, hence it is not known if the results would be the same if the follow-up time was a number of years. Further studies with longer follow-up periods would provide more knowledge in this area.

Another limitation of Study III was that the exact components of the program that contributed to the reduction in the prevalence of LBP and the reduction in pain and disability could not be determined. However, the efficacy of the specific exercise physiotherapy intervention has been investigated in a further study amongst this

cohort[57]. From this study it was found that the individualised specific exercise was found to be effective in reducing the prevalence of LBP in a population of adolescent female rowers and reducing pain levels in subjects who complained of LBP at the commencement of the rowing season.

5.5 RECOMMENDATIONS FOR FUTURE RESEARCH

In the light of the findings of this thesis and the acknowledged limitations, several recommendations can be made for future research. Future studies with a randomised controlled design and long term follow up periods that control for the components of the intervention would assist in evaluating the true effectiveness of the intervention program. In addition, further research with tighter control for the secondary outcome variables and including a kinematic analysis of rowing would be of interest. Research that distinguishes between performance type measures and measures of functional posture whilst rowing would assist in determining physical predictor variables of LBP. This research should include regional postures of the lumbar spine rather than the global lumbar spine kinematics.

Future cross-sectional research to include males, and older and more experienced rowers would also assist in identifying LBP risk factors to drive informed intervention with these additional sub-groups.

It would also be of interest to investigate the drop off in participation in the Schoolgirls rowing program from Year 9 to Year 10, and if this does exist, if LBP is a contributing factor to the decrease in participation in the sport.

5.6 CONCLUSIONS

In this thesis there were several conclusions of interest and these are listed below.

- LBP is common in schoolgirl rowers and they have moderate levels of pain and a large percentage (28.4%) with clinically significant levels of LBP-related disability. These findings are of concern as the first episode of LBP is a risk factor for LBP later in life.

- Sudden training load applied to rowers that are new to the sport (Year 9 rowers) may increase the risk of LBP.
- There are several mechanical factors (training time, rowing in sweep boats, sitting, lifting) that bring on, or exacerbate LBP in schoolgirls rowers.
- Schoolgirl rowers with LBP mainly present with clinically classified deficits in flexion or multi-directional segmental spinal control.
- Factors associated with LBP in Schoolgirl rowers include; reduced lower limb and back muscle endurance and a general pattern for less accuracy and greater variability in repositioning sense.
- Rowers classified with deficits in flexion or multi-directional segmental spinal control displayed greater joint hypermobility when compared with those without LBP.
- Schoolgirl rowers have a high incidence of LBP, however, a multi-dimensional intervention can be implemented to decrease the levels of pain and disability amongst this cohort.

It is of interest that the findings support the multi-factorial and bio-psycho-social nature of LBP and that multi-dimensional intervention is successful in reducing the prevalence of LBP in this schoolgirl rowing cohort. Modifiable personal factors should remain the focus of LBP prevention and management strategies, combined with education and controlled training practices. Multi-dimensional interventions applied when schoolgirl rowers are young, and possibly continued throughout the rowing career utilising a prevention approach that targets the modifiable risk indicators may have the potential to even further reduce the prevalence of LBP in this group.

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APPENDICES

Appendix A – Ethical Approval: Study I and Study II

To	Dr Angus Burnett, Physiotherapy
From	Dr Stephan Millett, Executive Officer, Human Research Ethics Committee
Subject	Protocol Approval **HR 80/2005**
Date	10 June 2005
Copy	

Thank you for your application submitted to the Human Research Ethics Committee (HREC) for the project titled *"An examination of low back pain in schoolgirls rowers - study 1"*.

Your application has been reviewed by members of the HREC reviewing panel who have recommended that your application be **APPROVED**.

- You are authorised to commence your research as stated in your proposal.
- The approval number for your project is **HR 80/2005**. *Please quote this number in any future correspondence*.
- Approval of this project is for a period of twelve months **10/06/2005** to **9/06/2005**.

If you are a Higher Degree by Research student, data collection must not begin before your Application for Candidacy is approved by your Divisional Graduate Studies Committee.

Applicants should note the following:

- It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants.
- All recommendations for approval are referred to the next meeting of the HREC for ratification. In the event the Committee does not ratify the recommendation, or would like further information, you will be notified. **The next meeting of the HREC is on 21/06/2005.**

The attached **FORM B** is to be completed and returned as soon as possible to the Secretary, HREC, C/- Office of Research & Development:

- When the project has finished, or
- If at any time during the twelve months changes/amendments occur, or
- If a serious or unexpected adverse event occurs.

Please find attached your protocol details together with the application form/cover sheet.

Dr Stephan Millett
Executive Officer
Human Research Ethics Committee

Please Note: The following standard statement must be included in the information sheet to participants:

This study has been approved by the Curtin University Human Research Ethics Committee. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784.

Appendix B - Questionnaire for Participants: Study I

The Schoolgirls' rowing population are invited to complete the questionnaire below. From those who complete the questionnaire a sample of 60 girls will be invited to participate in some additional testing by Physiotherapists at Curtin University to investigate the physical attributes of each rower. This group will also complete additional questionnaires relating to general activity levels and beliefs about low back pain. Participation in this additional testing is optional.

Thankyou for taking the time to complete the following questions.

Name:

School: _____

_____

Year (please tick)

Yr 9	
Yr 10	
Yr 11	
Yr 12	

Rowing Experience (please tick)

First Season	
Second Season	
Third Season	
Fourth Season	
> Four Seasons	

Date of Birth: _____

Height (cms): _____

Weight (kgs): _____

Other Sporting interests

_____

_____

_____

_____

_____

1. Have you ever experienced lower back Pain? Yes ☐ No ☐

If no, skip to Question 4

2. If yes, do you currently experience lower back pain whilst Rowing? Yes ☐ No ☐

3. When do you first remember experiencing LBP and how did it come about?

_____

_____

_____

4. Please indicate by ticking the boat(s) you **race** in regularly.

Sweep Eight ☐
Quad Scull ☐
Individual Scull ☐

5. On average how many hours per week in rowing related training?

On Water ☐
On land ☐

6. Of the sessions on water, please rank from most frequent to least frequent the boat you **train in** (1 = most frequent)

Sweep Eight ☐
Quad Scull ☐
Individual Scull ☐

7. On average how many hours per week at the moment do you spend doing physical activity other than rowing?

0 hours ☐
Less than 5 hours ☐
Greater than 5 hours ☐

Please complete the following two pages only if you do experience Low Back Pain.

Please put a mark on the scale to show how bad your ***usual*** pain is in the last week.

NO PAIN ☐_____☐ WORST POSSIBLE PAIN

From Ogon et al. (1996). Chronic low back pain measurement with visual analogue scales in different settings. Pain, 64, 425-428.

We are interested in knowing which activities bring on your back pain. Please place a tick in any of the boxes if you feel low back pain when doing any of the following activities:

☐ Lifting a rowing shell. Eg. On and off the water, or loading the trailer

☐ Sweep rowing (in an Eight)

☐ Rowing in a Quadruple Scull

☐ Rowing in a Single Scull

☐ Ergometer Rowing

☐ Long rows in a training session

☐ Other, please specify

_____

_____

_____

Appendix C - Questionnaire for Non-Rowers: Study I

A sample of IGSSA Schoolgirls are invited to complete the questionnaire below. This information will be used to compare findings to students who are participating in Rowing amongst the IGSSA population.

Thank you for taking the time to complete the following questions.

Name:

School: _____

_____

Year (please tick)

Yr 9	
Yr 10	
Yr 11	
Yr 12	

Date of Birth: _____

Height (cms): _____

Weight (kgs): _____

1. Have you ever experienced lower back Pain?

Yes ☐

If no, skip to Question 4 on page 3

No ☐

2. If yes, do you currently experience lower back pain whilst playing sport?

Yes ☐

No ☐

3. When do you first remember experiencing LBP and how did it come about?

_____

_____

_____

4. Please indicate by ticking the sports you have participated in the IGSSA competition this year.

Swimming ☐

Volleyball ☐

Tennis ☐

Gymnastics ☐

Cross Country ☐

Netball ☐

Rowing ☐

Hockey ☐

Athletics ☐ Events _____

Basketball ☐

Softball ☐

5. On average how many hours per week in IGSSA related training? ☐

6. On average how many hours per week at the moment do you spend doing physical activity other than IGSSA sport?

0 hours ☐

Less than 5 hours ☐

Greater than 5 hours ☐

7. If you participate in sports other than IGSSA sports please list them

_____

_____

_____

Please complete the following two pages only if you do experience Low Back Pain.

Please put a mark on the scale to show how bad your ***usual*** pain is in the last week.

NO PAIN ☐_____☐ WORST POSSIBLE PAIN

From Ogon et al. (1996). Chronic low back pain measurement with visual analogue scales in different settings. Pain, 64, 425-428.

Appendix D - Modified Oswestry Questionnaire

Modified Oswestry Questionnaire

This questionnaire has been designed to provide information on how your low back pain has affected your ability to manage in everyday life. Please answer every section, and mark in each section only ***one box*** that applies to you. We realise you may consider that two of the statements in any one section relate to you, but please ***just mark the box which closely describes your problem***.

Section 1 – Pain Intensity

- ☐ I can tolerate the pain I have without having to use pain killers
- ☐ The pain is bad but I manage without taking pain killers
- ☐ Pain killers give complete relief from pain
- ☐ Pain killers give moderate relief from pain
- ☐ Pain killers have no effect on the pain and I do not use them

Section 2 – Personal Care (Showering, Dressing etc)

- ☐ I can look after myself normally without causing extra pain
- ☐ I can look after myself normally but it causes extra pain
- ☐ It is painful to look after myself and I am slow and careful
- ☐ I need help every day in most aspects of self care
- ☐ I do not get dressed, wash with difficulty and stay in bed

Section 3 – Lifting

- ☐ I can lift heavy weights without extra pain
- ☐ I can lift heavy weights but it gives extra pain
- ☐ Pain prevents me from lifting heavy weight off the floor, but I can manage if they are conveniently positioned, eg on a table
- ☐ Pain prevents me from lifting heavy weights but I can manage light to medium weights if they are conveniently positioned
- ☐ I cannot lift or carry anything at all

Section 4 – Walking

- ☐ Pain does not prevent me walking any distance
- ☐ Pain prevents me walking more than 800m
- ☐ Pain prevents me walking more than 400m
- ☐ Pain prevents me walking more than 200m
- ☐ I can only walk using a stick or crutches
- ☐ I am in bed most of the time and have to crawl to the toilet

Section 5 – Sitting

- ☐ I can sit in any chair as long as I like
- ☐ I can only sit in my favourite chair as long as I like
- ☐ Pain prevents me from sitting more than 1 hour
- ☐ Pain prevents me from sitting more than ½ hour
- ☐ Pain prevents me from sitting more than 10 mins
- ☐ Pain prevents me from sitting at all

Section 6 – Standing

- ☐ I can stand as long as I want without extra pain
- ☐ I can stand as long as I want but it gives me extra pain
- ☐ Pain prevents me from standing for more than 1 hour
- ☐ Pain prevents me from standing for more than 30 mins
- ☐ Pain prevents me from standing for more than 10 mins
- ☐ Pain prevents me from standing at all

Section 7 – Sleeping

- ☐ Pain does not prevent me from sleeping well
- ☐ I can sleep well only by using tablets
- ☐ Even when I take tablets I have less than six hours sleep
- ☐ Even when I take tablets I have less than four hours sleep
- ☐ Even when I take tablets I have less than two hours sleep
- ☐ Pain prevents me from sleeping at all

Section 8 – Social Life

- ☐ My social life is normal and gives me no extra pain
- ☐ My social life is normal but increases the degree of pain
- ☐ Pain has no significant effect on my social life apart from limiting my more energetic interests, e.g. dancing , sport
- ☐ Pain has restricted my social life to home
- ☐ I have no social life because of pain

Section 9 – Travelling

- ☐ I can travel anywhere without extra pain.
- ☐ I can travel anywhere but it gives me extra pain
- ☐ Pain is bad but I manage journeys over two hours
- ☐ Pain restricts me to journeys of less than one hour
- ☐ Pain restricts me to short necessary journeys under 30 minutes
- ☐ Pain prevents me from travelling except to the doctor or hospital

Comments

_____

_____

_____

_____

Thank you for taking the time to complete this questionnaire

Appendix E - Back Beliefs Questionnaire

(Adapted from Symonds et al 1995)

We are trying to find out what people think about low back trouble. Please indicate your general views towards back trouble, even if you have never had any. Please answer ALL statements and indicate whether you agree or disagree with each statement by circling the appropriate number on the scale.

1 = COMPLETELY DISAGREE, 5 = COMPLETELY AGREE

1	2	3	4	5
Completely disagree				Completely agree

		Disagree				Agree
1	There is no real treatment for back trouble	1	2	3	4	5
2	Back trouble will eventually stop you from participation in physical activity	1	2	3	4	5
3	Back trouble means periods of pain for the rest of one's life	1	2	3	4	5
4	Doctors cannot do anything for back trouble	1	2	3	4	5
5	A bad back should be exercised	1	2	3	4	5
6	Back trouble makes everything in life worse	1	2	3	4	5
7	Surgery is the most effective way to treat back trouble	1	2	3	4	5
8	Back trouble may mean you end up in a wheelchair	1	2	3	4	5
9	Alternative treatments are the answer to back trouble	1	2	3	4	5
10	Back trouble means long periods of time off school	1	2	3	4	5
11	Medication is the only way of relieving back trouble	1	2	3	4	5
12	Once you have had back trouble there is always a weakness	1	2	3	4	5
13	Back trouble must be rested	1	2	3	4	5
14	Later in life back trouble gets progressively worse	1	2	3	4	5

Appendix F - Child Behaviour Checklist

Child Behaviour Checklist for Ages 11-18

Please Print

TODAY'S DATE Month _____ Date _____ Yr _____ ETHNIC GROUP OR RACE_____	**PARENTS' USUAL TYPE OF WORK**, even if not working now (Please be specific – for example, auto mechanic, high school teacher, homemaker, labourer, lathe operator, shoe salesman, army sergeant.) FATHER'S TYPE OF WORK: _____ MOTHER'S TYPE OF WORK: _____ Please fill out this form to reflect your views, even if other people might not agree. Feel free to print additional comments beside each item and in the spaces provided on pages 2 and 4.

1. Please list the sports you most like to Take part in. For example: swimming, Baseball, skating, skate boarding, bike Riding, fishing, etc.	Compared to others of your age, about how much time do you spend in each?			Compared to others of your age, how well do you do each one?		
☐ None	Less Than Average	Below Average	Above Average	Above Average	Above Average	More Than Average
a. _____	☐	☐	☐	☐	☐	☐
b. _____	☐	☐	☐	☐	☐	☐
c. _____	☐	☐	☐	☐	☐	☐

11. Please list your favourite hobbies, activities and games, other than sports. For example: cards, books, piano, cars, crafts, etc. (Do not include listening to radio or TV.)	Compared to others of your age, about how much time do you spend in each?			Compared to others of your age, how well do you do each one?		
☐ None	Less Than Average	Below Average	Above Average	Above Average	Above Average	More Than Average
d. _____	☐	☐	☐	☐	☐	☐
e. _____	☐	☐	☐	☐	☐	☐
f. _____	☐	☐	☐	☐	☐	☐

111. **Please list any organisation, clubs, Teams or groups you belong to.**

☐ **None**

Compared to others of your age, how active are you in each?

		Less Active	Average	More Active
a.	_____	☐	☐	☐
b.	_____	☐	☐	☐
c.	_____	☐	☐	☐

IV. **Please list any jobs or chores you have. For example: paper route, babysitting, Making bed, working in store, etc. (Include both paid and unpaid jobs and chores.)**

☐ **None**

Compared to others of your age, how well do you carry them out?

		Below Average	Average	Above Average
a.	_____	☐	☐	☐
b.	_____	☐	☐	☐
c.	_____	☐	☐	☐

---

1. **About how many close friends do you have? (Do not include brothers & sisters)** ☐ NONE ☐ 1 ☐ 2 or 3 ☐ 4 or more

2. **About how many times a week do you do things with any friends outside of regular school hours? (Do not include brothers & sisters)** ☐ Less than 1 ☐ 1 or 2 ☐ 3 or more

---

I. **Compared to others of your age, how well do you:**

		Worse	About Average	Better	
a.	Get along with your brothers & sisters?	☐	☐	☐	☐ I have no brothers or sisters
b.	Get along with other kids?	☐	☐	☐	
c.	Get along with your parents?	☐	☐	☐	
d.	Do things by yourself?	☐	☐	☐	

II. **Performance in academic subjects**.

Check a box for each subject that you take	**Failing**	**Below Average**	**Average**	**Above Average**
a. English or Language Arts	☐	☐	☐	☐
b. History or Social Studies	☐	☐	☐	☐
c. Arithmetic or Math	☐	☐	☐	☐
d. Science	☐	☐	☐	☐
e. _____	☐	☐	☐	☐
f. _____	☐	☐	☐	☐
g. _____	☐	☐	☐	☐

(Other academic subjects – for example: computer courses, foreign language, business. Do not include gym, shop, driver's ed., etc.)

Do you have any illness, disability or handicap? ☐ **NO** ☐ **YES – please describe**:

Please describe any concerns or problems you have about school:

Please describe any other concerns you have:

Please describe the best things about yourself:

Below is a list of items that describe kids. For each item that describes you now or **within the past 6 months**, please circle the **2** if the item is **very true or often true** of you. Circle the **1** if the item is **somewhat** or **sometimes true** of you. If the item is not true of you, circle the **0**.

Please Print **0 = Not True** **1 = Somewhat or Sometimes True** **2 = Very True or Often True**

0	1	2	1. I act too young for my age	0	1	2	46. Parts of my body twitch or make nervous movements (describe): _____
0	1	2	2. I have an allergy (describe): _____				_____
			_____				_____
0	1	2	3. I argue a lot	0	1	2	47. I have nightmares
0	1	2	4. I have asthma.	0	1	2	48. I am not liked by other kids
0	1	2	5. I act like the opposite sex	0	1	2	49. I can do certain things better than most kids
0	1	2	6. I like animals	0	1	2	50. I am too fearful or anxious
0	1	2	7. I brag	0	1	2	51. I feel dizzy
0	1	2	8. I have trouble concentrating or paying attention	0	1	2	52. I feel too guilty
0	1	2	9. I can't get my mind off certain thoughts (describe):	0	1	2	53. I eat too much
				0	1	2	54. I feel overtired
			_____	0	1	2	55. I am overweight
			_____	0	1	2	56. Physical problems without known medical cause:
							a. Aches or pains (not stomach or headaches)
			_____				b. Headaches
							c. Nausea, feel sick
0	1	2	10. I have trouble sitting still				d. Problems with eyes (not if corrected by glasses) (describe):
0	1	2	11. I'm too dependent on adults				_____
0	1	2	12. I feel lonely				_____
0	1	2	13. I feel confused or in a fog				_____
0	1	2	14. I cry a lot				
0	1	2	15. I am pretty honest				
0	1	2	16. I am mean to others				
0	1	2	17. I daydream a lot				e. Rashes or other skin problems
0	1	2	18. I deliberately try to hurt or kill myself				f. Stomach aches or cramps
0	1	2	19. I try to get a lot of attention				g. Vomiting, throwing up
0	1	2	20. I destroy my own things				h. Other (describe): _____
0	1	2	21. I destroy things belonging to others				
0	1	2	22. I disobey my parents				_____
0	1	2	23. I disobey at school				
0	1	2	24. I don't eat as well as I should				_____
0	1	2	25. I don't get along with other kids				
0	1	2	26. I don't feel guilty after doing something I shouldn't	0	1	2	57. I physically attack people
0	1	2	27. I am jealous of others	0	1	2	58. I pick my skin or other parts of my body (describe):
0	1	2	28. I am willing to help others when they need help				
0	1	2	29. I am afraid of certain animals, situations or places, other than school (describe): _____				_____
							_____
			_____				_____
0	1	2	30. I am afraid of going to school				
0	1	2	31. I am afraid I might think or do something bad	0	1	2	59. I can be pretty friendly
0	1	2	32. I feel that I have to be perfect	0	1	2	60. I like to try new things
0	1	2	33. I feel that no one loves me	0	1	2	61. My school work is poor
0	1	2	34. I feel that others are out to get me	0	1	2	62. I am poorly co-ordinated or clumsy
0	1	2	35. I feel worthless or inferior	0	1	2	63. I would rather be with older kids than with kids my own age
0	1	2	36. I accidentally get hurt a lot				
0	1	2	37. I get in many fights	0	1	2	64. I would rather be with younger kids than with kids my own age
0	1	2	38. I get teased a lot				
0	1	2	39. I hang around with kids who get in trouble	0	1	2	65. I refuse to talk
			40. I hear sounds or voices that other people think aren't there (describe): _____	0	1	2	66. I repeat certain acts over and over (describe):
							_____
			_____	0	1	2	67. I run away from home
				0	1	2	68. I scream a lot
0	1	2	41. I act without stopping to think	0	1	2	69. I am secretive or keep things to myself
0	1	2	42. I would rather be alone than with others	0	1	2	70. I see things that other people think aren't there (describe):
0	1	2	43. I lie or cheat				_____
0	1	2	44. I bite my fingernails				
0	1	2	45. I am nervous or tense				_____

0	1	2	71. I am self-conscious or easily embarrassed	0	1	2	91. I think about killing myself
0	1	2	72. I set fires	0	1	2	92. I like to make others laugh
0	1	2	73. I can work well with my hands	0	1	2	93. I talk too much
0	1	2	74. I show off or clown	0	1	2	94. I tease others a lot
0	1	2	75. I am shy	0	1	2	95. I have a hot temper
0	1	2	76. I sleep less than most kids	0	1	2	96. I think about sex too much
0	1	2	77. I sleep more than most kids during day and/or night (describe): _____	0	1	2	97. I threaten to hurt people
				0	1	2	98. I like to help others
				0	1	2	99. I am too concerned about being neat or clean
			_____	0	1	2	100. I have trouble sleeping (describe):
			_____				_____
0	1	2	78. I have a good imagination				_____
0	1	2	79. I have a speech problem (describe): _____				_____
			_____	0	1		101. I cut classes or skip school
			_____	0	1		102. I don't have much energy
				0	1		103. I am unhappy, sad or depressed
			_____	0	1		104. I am louder than other kids
				0	1		105. I use alcohol or drugs for non-medical purposes
0	1	2	80. I stand up for my rights				(described): _____
0	1	2	81. I steal at home				_____
0	1	2	82. I steal from places other than home				
0	1	2	83. I store up things I don't need (describe):				_____
			_____				_____
			_____	0	1	2	106. I try to be fair to others
			_____	0	1	2	107. I enjoy a good joke
				0	1	2	108. I like to take life easy
0	1	2	84. I do things other people think are strange (describe):	0	1	2	109. I try to help other people when I can
				0	1	2	110. I wish I were of the opposite sex
			_____	0	1	2	111. I keep from getting involved with others
			_____	0	1	2	112. I worry a lot
			_____				
0	1	2	85. I have thoughts that other people would think are strange (describe): _____				
			_____				
			_____				
0	1	2	86. I am stubborn				
0	1	2	87. My moods or feelings change suddenly				
0	1	2	88. I enjoy being with other people				
0	1	2	89. I am suspicious				
0	1	2	90. I swear or use dirty language				

Appendix G – Tampa Scale of Kinesiophobia

Assessment of movement with Low Back Pain

Here are some of the things which other patients have told us about their pain. For each statement please circle any number from 1 to 4 to signify whether you agree or disagree with the statement.

	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1. I'm afraid that I might injure myself if I exercise.	1	2	3	4
2. If I were to try to overcome it, my pain would increase.	1	2	3	4
3. My body is telling me I have something dangerously wrong.	1	2	3	4
4. My pain would probably be relieved if I were to exercise.	1	2	3	4
5. People aren't taking my medical condition seriously.	1	2	3	4
6. My accident has put my body at risk for the rest of my life.	1	2	3	4
7. Pain always means I have injured my body.	1	2	3	4
8. Just because something aggravates my pain does not mean it is dangerous.	1	2	3	4
9. I am afraid that I might injure myself accidentally.	1	2	3	4
10. Simply being careful that I do not make any unnecessary movements is the safest thing I can do to prevent my pain from worsening.	1	2	3	4
11. I wouldn't have this much pain if there weren't something potentially dangerous going on in my body.	1	2	3	4
12. Although my condition is painful, I would be better off if I were physically active.	1	2	3	4
13. Pain lets me know when to stop exercising so that I do not injure myself.	1	2	3	4
14. It's really not safe for a person with a condition like mine to be physically active.	1	2	3	4
15. I can't do all the things normal people do because it's too easy for me to get injured.	1	2	3	4
16. Even though something is causing me a lot of pain, I don't think it's actually dangerous.	1	2	3	4
17. No one should have to exercise when he/she is in pain.	1	2	3	4

Tampa scale for kinesiophobia Reprinted from *Pain*, 62: 363-372 with permission from Elsevier Science.

Vlaeyen J, Kole-Snijders A, Boersen R, van Eek H. (1995) Fear of movement/(re)injury in chronic low back pain and its relation to behavioural performance

Appendix H - International Physical Activity Questionnaire

International Physical Activity Questionnaire (From Booth, 2000)

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and **make you breathe much harder than normal**. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

_____ **days per week**

☐ No vigorous physical activities → ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and **make you breathe somewhat harder than normal**. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

_____ **days per week**

☐ No moderate physical activities → ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at school and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ **days per week**

☐ No walking → ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at school, at home, while doing home work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Appendix I – Spinal Kinematics/Spinal Proprioception Calculations

With data recorded using Fastrak the lumbar repositioning (displacement) was calculated as well as repositioning errors for each of the trunk angles (lower lumbar angle, lumbar angle and upper lumbar angle).

Lumbar repositioning in centimeters was determined in Excel by calculating the average position for each sensor when the subject was in both the neutral spine position and when they attempted to reposition to this neutral spine position. The error at each sensor was then determined by calculating the displacement between the sensors and then these were averaged to determine the error for each trial. The lumbar repositioning for each trial was then averaged to determine the overall lumbar repositioning.

The repositioning error (RE) was defined using the two translation coordinates of each sensor (up and forward) relative to the source and the resultant of these coordinates was then calculated. The RE for the trial as an angle was calculated by firstly averaging the values of the three sensors. This data was then transformed in Excel. The process for this is outlined below.

Data output by the Fastrak were in the form of Cardan angles (ZYX sequence). As an alternative rotation sequence and representation system was preferred, a number of data transformations were necessary. Firstly, each average data record containing three Cardan angles was converted into the elements of their respective direction cosine matrices by the following equations;-

$R_{11} = \cos\theta \cos\varphi$

$R_{12} = \cos\theta \sin\varphi \sin\psi - \sin\theta \cos\psi$

$R_{13} = \cos\theta \sin\varphi \cos\psi + \sin\theta \sin\psi$

$R_{21} = \sin\theta \cos\varphi$

$R_{22} = \sin\theta \sin\varphi \sin\psi + \cos\theta \cos\psi$

$R_{23} = \sin\theta \sin\varphi \cos\psi - \cos\theta \sin\psi$

$R_{31} = -\sin\varphi$

$R_{32} = \cos\varphi \sin\psi$

$R_{33} = \cos\varphi \cos\psi$

Where the direction cosine matrix R was defined as:

$$R = \begin{bmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{bmatrix}$$

Secondly, in order to measure orientation relative to a zero reference the following transformation was applied to the data:-

$$[R_C] = [R_A]^T [R_B]$$

Where $[R_A]$ was the direction cosine matrix of the of the inferior angle data and $[R_B]$ was the direction cosine matrix of the superior angle data, while $[R_A]^T$ was the transpose of $[R_A]$.

Eg. To calculate upper lumbar angle with sensor 3 on T12 and sensor 2 on L3 by measuring the orientation relative to a zero reference

$$[R_C] = [R \text{ sensor } 2]^T [R \text{ sensor } 3]$$

The angles β, α and γ which corresponded to lateral bending, flexion/extension and axial rotation respectively were then recovered from the directional cosine matrix $[R_C]$ via the following functions:-

$$\beta = Tan^{-1}\left[\frac{R_{C21}}{\sqrt{R_{C31}^2 + R_{C11}^2}}\right]$$

$$\alpha = Tan^{-1}\left[\frac{-R_{C31}}{R_{C11}}\right]$$

$$\gamma = = Tan^{-1}\left[\frac{-R_{C23}}{R_{C22}}\right]$$

The difference in angle was calculated by subtracting the repositioning angle from the criteria angle. Three measures relating to lower lumbar, upper lumbar and lumbar angles were used to estimate repositioning ability they being; constant error (CE), absolute error (AE) and variable error (VE). CE is a measure of bias considered as the signed difference between the criterion and finish positions, with a positive CE indicating overshooting of the criterion position. AE is the unsigned difference between the criterion and the finish positions and reflected repositioning accuracy only. AE and CE were averaged over three trials. VE represented the variability of an individual's CE measure and represents repeatable precision. In this study VE was calculated as the SD of the three trials of CE of the one individual. High VE reflected high variability in repositioning ability, whilst low VE reflected low variability of positioning.

Appendix J – Child Behaviour Checklist Data: Study II

Table J.1: Psycho-social variables (mean ± standard deviation) for the no-LBP and LBP groups using the Child Behaviour Checklist

	No LBP (N=30)	LBP (N=30)	p-value	Cohen's d	95% Confidence Interval	LBP Flexion and Multi-directional (N=19)	p-value	Cohen's d	95% Confidence Interval
Anxious/Depressed /26	5.2 ± 3.1	4.7 ± 3.5	0.562	0.15	-1.2 – 2.2	5.5 ± 3.9	0.761	-0.09	-2.3 – 1.7
Withdrawn/Depressed /16	2.7 ± 1.6	2.5 ± 2.4	0.751	0.10	-0.9 – 1.2	2.6 ± 2.7	0.955	0.05	-1.2 – 1.3
Somatic Complaints /20	2.9 ± 2.5	3.7 ± 3.1	0.292	-0.29	-2.2 – 0.7	4.1 ± 3.3	0.186	-0.41	-2.8 – 0.6
Social Problems /22	2.7 ± 1.7	3.2 ± 2.8	0.408	-0.22	-1.7 – 0.7	3.2 ± 2.8	0.437	-0.22	-1.8 – 0.8
Thought Problems /24	4.1 ± 3.1	3.7 ± 2.8	0.601	0.14	-1.1 – 1.9	4.4 ± 3.2	0.701	-0.10	-2.2 – 1.5
Attention Problems /18	4.9 ± 2.2	5.4 ± 3.0	0.532	-0.19	-1.8 – 0.9	5.6 ± 3.4	0.427	-0.25	-2.3 – 1.0
Rule-breaking Behaviour /30	3.0 ± 3.0	3.7 ± 3.2	0.388	-0.23	-2.3 – 0.9	4.4 ± 3.8	0.166	-0.41	-3.3 – 0.6
Aggressive Behaviour /34	5.5 ± 3.6	6.1 ± 4.3	0.571	-0.08	-2.7 – 1.4	6.7 ± 4.8	0.295	-0.29	-3.7 – 1.1
Other	4.5 ± 1.9	4.8 ± 1.9	0.585	-0.16	-1.2 – 0.7	5.4 ± 2.1	0.132	-0.45	-2.0 – 0.3
Internalising /62	10.8 ± 5.5	10.9 ± 7.2	0.952	-0.02	-3.4 – 3.2	12.2 ± 8.4	0.484	-0.20	-5.4 – 2.6
Externalising /64	8.5 ± 6.0	9.9 ± 7.1	0.427	-0.21	-4.7 – 2.1	11.1 ± 8.3	0.204	-0.36	-6.8 – 1.5
TOTAL	35.4 ± 14.8	37.7 ± 21.2	0.633	-0.13	-11.1 – 7.2	41.8 ± 24.7	0.260	-0.32	-17.7 – 4.9

Table J.2: Number (and proportion) of rowers who participated in further testing classified as clinical risk or borderline clinical risk for the eight scales and the total score in the Child Behaviour Checklist.

	No LBP (N=30)		**LBP (N=30)**		**LBP Flexion and Multidirectional (N=19)**	
	Borderline	Clinical	Borderline	Clinical	Borderline	Clinical
1.Anxious/Depressed	1 (3.3%)	0 (0%)	2 (6.7%)	0 (0%)	2 (10.5%)	0 (0%)
2.Withdrawn/Depressed	0 (0%)	0 (0%)	0 (0%)	1 (3.3%)	0 (0%)	1 (5.3%)
3.Somatic Complaints	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (5.3%)	1 (5.3%)
4.Social Problems	0 (0%)	0 (0%)	2 (6.7%)	1 (3.3%)	2 (10.5%)	0 (0%)
5.Thought Problems	2 (6.7%)	0 (0%)	2 (6.7%)	0 (0%)	2 (10.5%)	0 (0%)
6.Attention Problems	1 (3.3%)	0 (0%)	0 (0%)	2 (6.7%)	0 (0%)	2 (10.5%)
7.Rule Breaking Behaviour	1 (3.3%)	0 (0%)	3 (10.0%)	0 (0%)	3 (15.8%)	0 (0%)
8.Aggressive Behaviour	2 (6.7%)	0 (0%)	3 (10.0%)	0 (0%)	3 (15.8%)	0 (0%)
Internalising (1+2+3)	1 (3.3%)	0 (0%)	2 (6.7%)	1 (3.3%)	2 (10.5%)	1 (5.3%)
Externalising (7+8)	2 (6.7%)	0 (0%)	4 (13.3%)	0 (0%)	4 (21.1%)	0 (0%)
Total (Sum of all items)	1 (3.3%)	0 (0%)	3 (10.0%)	1 (3.3%)	3 (15.8%)	1 (5.3%)

Appendix K – Ethical Approval: Study III

memorandum

Curtin University of Technology

To	Dr Angus Burnett, School of Physiotherapy
From	Dr Stephan Millett, Executive Officer, Human Research Ethics Committee
Subject	Protocol Approval **HR 15/2006**
Date	16 March 2006
Copy	Ms Debra Perich , Physiotherapy A/Prof Peter O'Sullivan, Physiotherapy

Office of Research and Development

Human Research Ethics Committee

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL L Teasdale@curtin edu au

Thank you for your application submitted to the Human Research Ethics Committee (HREC) for the project titled "*Low Back Pain In Adolescent Female Rowers: A Multi-Disciplinary Intervention Study*".

Your application has been reviewed by members of the HREC reviewing panel who have recommended that your application be **APPROVED**. The response from the sub-committee is detailed below:

(i). The consent form for the intervention group should include acknowledging the $60 screening cost.

(ii). Care has been taken in the design of the research to protect the rights of minors in schools. Given the Physical nature of a number of the tests and under duty of care it may be in the best interests of the students, schools and the research to have a qualified staff member present along with the investigator

- You are authorised to commence your research as stated in your proposal.
- The approval number for your project is **HR 15/2006**. *Please quote this number in any future correspondence.*
- Approval of this project is for a period of twelve months **3/15/2006** to **3/15/2007**.

If you are a Higher Degree by Research student, data collection must not begin before your Application for Candidacy is approved by your Divisional Graduate Studies Committee.

Applicants should note the following:

- It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants.
- All recommendations for approval are referred to the next meeting of the HREC for ratification. In the event the Committee does not ratify the recommendation, or would like further information, you will be notified. **The next meeting of the HREC is on 4/4/2006.**

Appendix L – Questionnaire for Participants: Study III

The Schoolgirls' rowing population are invited to complete the questionnaire below as a follow up study from the research conducted during the 2005 Rowing season.

Thank you for taking the time to complete the following questions.

Name:

School: _____

_____

Year (please tick)

Yr 9	
Yr 10	
Yr 11	
Yr 12	

Rowing Experience (please tick)

First Season	
Second Season	
Third Season	
Fourth Season	
> Four Seasons	

Date of Birth: _____

Height (cms): _____

Weight (kgs): _____

Other Sporting interests

_____

_____

_____

_____

_____

1. Have you ever experienced lower back Pain? Yes ☐ No ☐

If no, skip to Question 4 on page 3

2. If yes, do you currently experience lower back pain whilst Rowing? Yes ☐ No ☐

3. When do you first remember experiencing LBP and how did it come about?

_____

_____

_____

_____

_____

We are interested in knowing which activities bring on your back pain. Please place a tick in any of the boxes if you feel low back pain when doing any of the following activities:

☐ Lifting a rowing shell. Eg. On and off the water, or loading the trailer

☐ Sweep rowing (in an Eight)

☐ Rowing in a Quadruple Scull

☐ Rowing in a Single Scull

☐ Ergometer Rowing

☐ Long rows in a training session

☐ Other, please specify

_____

_____

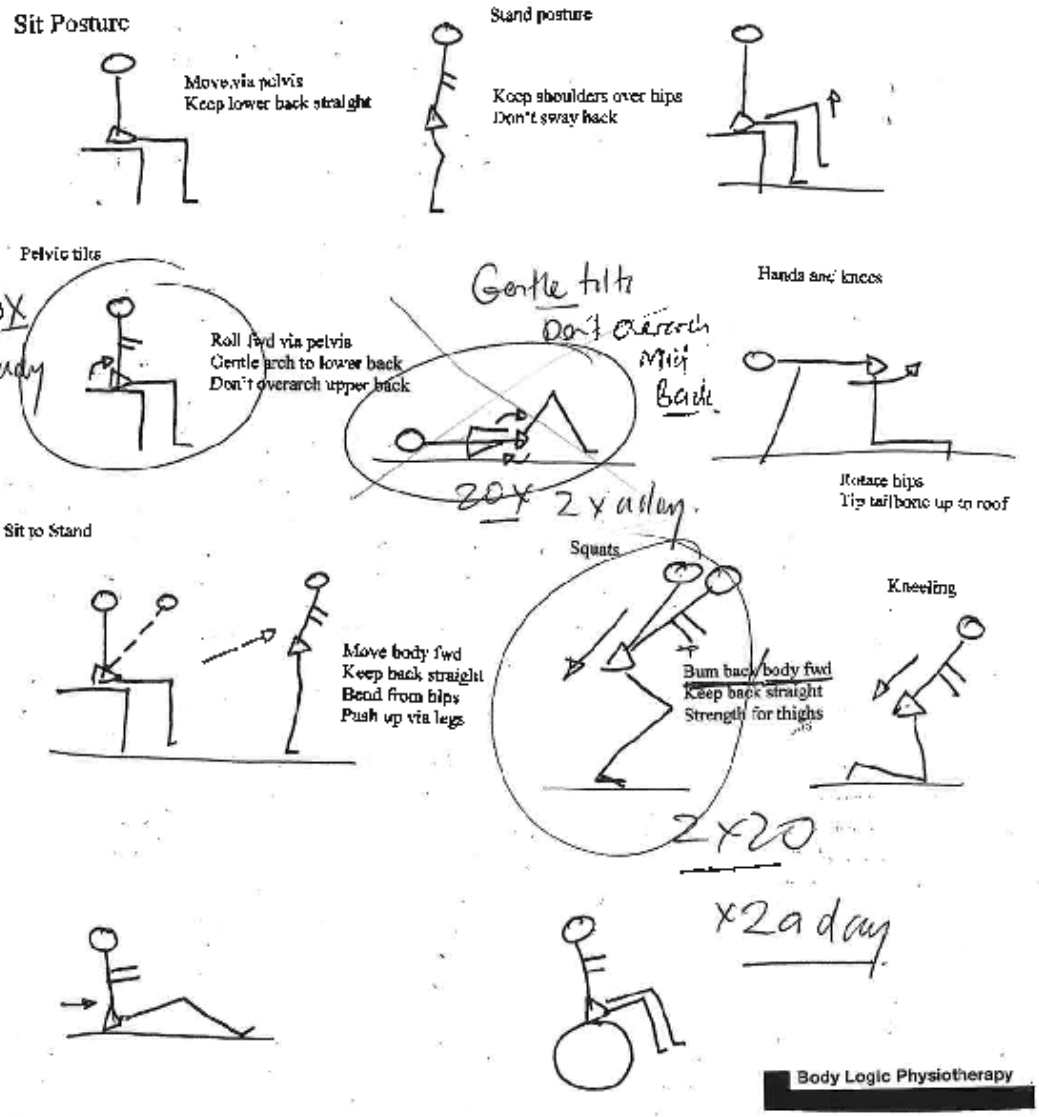
_____

4. Please indicate by ticking the boat(s) you **race** in regularly.	Sweep Eight	
	Quad Scull	
	Individual Scull	
5. On average how many hours per week in rowing related training?	On Water	
	On land	
6. Of the sessions on water, please rank from most frequent to least frequent the boat you **train in** (1 = most frequent)	Sweep Eight	
	Quad Scull	
	Individual Scull	
7. On average how many hours per week at the moment do you spend doing physical activity other than rowing?	0 hours	
	Less than 5 hours	
	Greater than 5 hours	

Appendix M – Sample Program from Musculoskeletal Screening: Study III

ROWING AND YOUR BACK
Perth College 2006

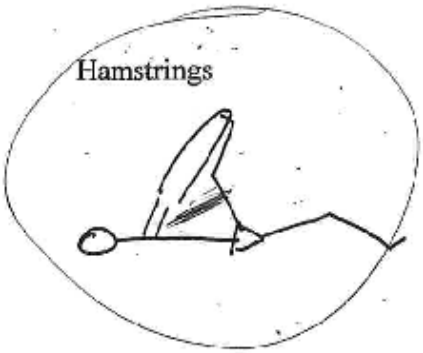
The rowing action involves significant levels of bending from the lower back.
This repetitive bending can increase the risk of back pain.
Back pain is the most common injury to rowers accounting for approximately 15-25%
There are many factors that will help you reduce the risk of back pain and these will be explained by the physiotherapist.
It is important to understand and do the exercises daily



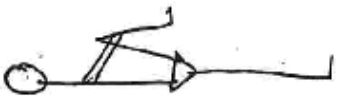
STRETCHES Hold 30 seconds x 2

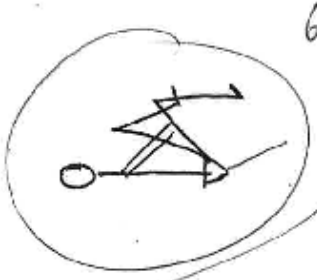
2 x a day

Hamstrings



Gluts





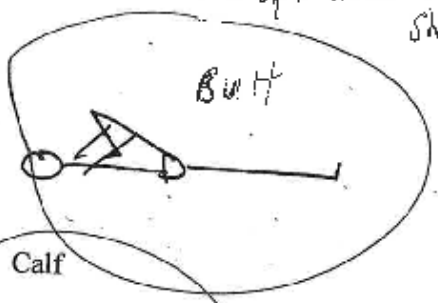
6 / 7 / 6

mild

hip pinch

knee up / across to opp shoulder

Butt



Calf

Appendix N – Sample Strength and Conditioning Sessions: Study III

Sample Fitness Circuit

1. Triangle – 50-75m apart, 5 each marker (25 mins)

    1 lap jog warm-up followed by a group stretch.

    Team of 5, 2 lots of 2 at 2 markers, 1 at other. Markers with 2, one person from each leaves at same time, and then tag relay from then on. - the quicker you run the more rest you get…

    1 full revolution to check girls understand.

    4-5 more full revolutions.

2. Ramp running – (10 mins)

    Leave 10m apart, try catch person in front of them.

    5 x up ramp, jog recovery.

3. Circuit – 2-3 circuit rounds – (10 mins)

    a) 6 laps length of gym

    b) bridge, hold 10 sec, rest 5 sec, up again

    c) step ups

    d) squats, hold 4 sec, up and repeat

    e) skipping

    f) super mans – opp leg and arm, hold 5 sec swap.

4. 4 laps walk recover

5. Own Musculoskeletal Program – (10-15 mins)

6. Stretch as a group.

Sample Fitness Session

Warm Up (5 mins)

With a partner, one Jogs, one hockey pitch, the other skips a rope.

Swap roles

Stretch, (5 mins)

Part one of session (20 Mins)

2 x 60% run half the hockey pitch with a walk recovery on the return.

6 x 90% run half the hockey pitch with a jog recovery on the return. Let the girls go at approx 5 m spacing. Receive a penalty if you get caught by the girl behind you. (some can be done up the ramp if the space permits)

1 x 90% full hockey pitch, jog recovery return.

Part two of session (20 mins)

Circuit – girls in partners.

One running across the gym (4 repeats – across and back = 1)

Other doing a different activity at the side of gym whilst they wait for the run to be completed. Swap when the runner returns.

Example activities:

Step ups

Bench blasts

Sit ups/crunches

Push ups

Skipping

** Add Squats, sit to stand.

Own program and stretch – (10-15 min)

A group long stretch.

Appendix O – Secondary Outcome Variable Data: Study III

Table O.1: Mean (±SD) secondary outcome variables measured at Start-season and End-season.

	Start-season	End-season	p-value
Lower limb endurance (sec)	60.2 ± 24.6	142.1 ± 71.6	<0.001
Back muscle endurance (sec)	83.5 ± 50.7	147.1 ± 65.4	<0.001
12 minute run (m)	1836.8 ± 302.8	2125.5 ± 256.6	<0.001
Sit and reach flexibility (cm)	2.4 ± 8.4	7.4 ± 7.8	<0.001
Usual/slump lower lumbar angle difference (º)	-6.5 ± 7.6	-12.4 ± 13.4	<0.001
Sacral tilt (º)	5.1 ± 7.6	11.4 ± 7.0	<0.001

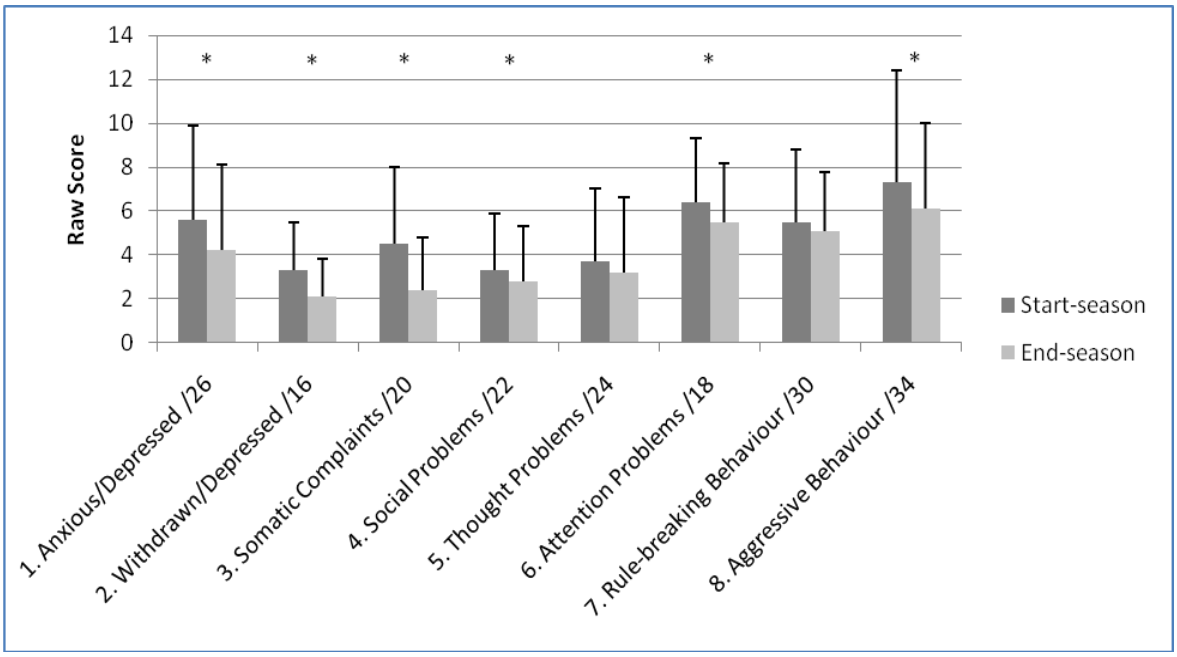


Figure O.1: Psycho-social variable data for the intervention group in Study III.

* p<0.05 indicates significant differences between Start-season and End-season.

Table O.2: Number (and proportion) of rowers in Study III classified as borderline clinical risk or clinical risk for the eight scales and the total score in the Child Behaviour Checklist

	Borderline		**Clinical**		**p-value**	**Borderline + Clinical**		**p-value**
	Start-season	**End-season**	**Start-season**	**End-season**		**Start-season**	**End-season**	
1.Anxious / Depressed	7 (8.9%)	3 (3.8%)	2 (2.5%)	3 (3.8%)		9 (11.4%)	6 (7.6%)	
2.Withdrawn / Depressed	3 (3.8%)	0 (0%)	0 (0%)	0 (0%)		3 (3.8%)	0 (0%)	
3.Somatic Complaints	9 (11.4%)	1 (1.3%)	3 (3.8%)	1 (1.3%)		12 (15.2%)	2 (2.5%)	
4.Social Problems	3 (3.8%)	7 (8.9%)	1 (1.3%)	0 (0%)		4 (5.1%)	7 (8.9%)	
5.Thought Problems	8 (10.1%)	4 (5.1%)	1 (1.3%)	2 (2.5%)		9 (11.4%)	6 (7.6%)	
6.Attention Problems	11 (13.9%)	4 (5.1%)	3 (3.8%)	2 (2.5%)		14 (17.7%)	6 (7.6%)	
7.Rule Breaking	7 (8.9%)	8 (10.1%)	2 (2.5%)	1 (1.3%)		9 (11.4%)	9 (11.4%)	
8.Aggressive Behaviour	9 (11.4%)	1 (1.3%)	2 (2.5%)	1 (1.3%)		11 (13.9%)	2 (2.5%)	
Internalising (1+2+3)	8 (10.1%)	7 (8.9%)	11 (13.9%)	2 (2.5%)	0.012 *	19 (24.1%)	9 (11.4%)	0.031 *
Externalising (7+8)	15 (19.0%)	6 (7.6%)	12 (15.2%)	8 (10.1%)	0.344	27 (34.2%)	14 (17.7%)	0.002 *
Total score (Sum of all items)	12 (15.2%)	6 (7.6%)	12 (15.2%)	5 (6.3%)	0.016 *	24 (34.2%)	11 (13.9%)	0.002 *

Note: * indicate a significant difference ($p<0.05$) between Start-season and End-season.

Appendix P – Participant Information Sheet: Study I

An Examination of Lower Back Pain in Schoolgirl Rowers – Questionnaires for LBP subset

A study conducted by the School of Physiotherapy, Curtin University of Technology

Rowing is one of the largest participant sports of the Independent Girls' Schools' Sports Association (IGSSA) in Western Australia with approximately 400 participants.

WHY are we conducting the study?

In a previous questionnaire that your daughter completed to determine the prevalence of LBP amongst the IGSSA rowing population a greater incidence of LBP appeared than the 10% that we anticipated. It became evident that it is necessary to rate the pain of this population prior to conducting the battery of physical tests on the LBP and no LBP populations in the second part of this study to determine the severity of the pain for the sufferers. Your daughter identified herself as one who currently experiences LBP.

HOW? What do I have to do?

Participation is voluntary. The series of questionnaires will take your daughter approximately 30 minutes to complete. They will include a Level of Pain, Modified Oswestry Questionnaire to determine level of disability, a Fear Avoidance Questionnaire, Back Beliefs Questionnaire and the International Physical Activity Questionnaire. We are hoping to get her to complete these during her Rowing Camp in the Term 2 holidays.

There will be no cost to you. The cost to your daughter will be her time to complete the questionnaire. There are no risks associated with participation in this research.

The benefit of participating in this study is that you and your child will help us to understand the status of the pain that the Schoolgirls rowing population are experiencing. Information about the findings of this study and recommendations will be made available to you via your school.

A second study will follow this one, where 30 of these rowers experiencing LBP will be invited to participate in a battery of physical tests and psycho-social measures to determine if rowers with and without LBP differ in these areas. Again, if your daughter is invited to participate in this second study, her involvement will be voluntary.

What if I do not want my child to take part in the first study?

If after reading this information sheet you decide you do not want your child to participate in the study, all you need to do is to fill in the attached form titled "Request to Exclude" and return it to her school or Rowing Co-ordinator by Monday 18th July, 2005. Your child will not be prejudiced in any way.

Will my child's information be kept confidential?

We are collecting your daughter's name so we can recognize her should we invite her to the second study. All other information collected will be anonymous.

What about the results of the study?

Detailed reports on the study will be published in international scientific journals. A report will also be presented to your school Principal when we have finished the study.

Has this study been approved?

This study has been approved by the Curtin University Human Research Ethics Committee. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784.

This study has also been approved by your Principal.

Questions? If you have any questions, queries or problems please contact Debra Perich: School Of Physiotherapy, Curtin University of Technology.

Phone: 0409 467 449, Email: deb@pc.wa.edu.au

Thank you

Debra Perich

Head of Physical Education Perth College

Masters candidate

School of Physiotherapy

Curtin University Of Technology

Dr Angus Burnett

Research Fellow

School of Physiotherapy

Curtin University Of Technology

Dr Peter O'Sullivan

School of Physiotherapy

Curtin University Of Technology

Appendix Q – Parent Information Sheet: Study II

An Examination of Low Back Pain in Schoolgirl Rowers

Dear Parent/Caregiver

Thank you for considering allowing your child to participate in this study. We would like to take the opportunity to investigate how young adolescents who are experiencing Lower Back Pain (LBP) whilst rowing use their bodies in a variety of simple functional tasks and compare how this differs to those without low back pain. We know in adults that such differences exist. We also know that correcting the way people use their bodies is important in treating adult patients with low back pain. Little is known about LBP in adolescents, and the importance of the postures that they naturally choose while sitting and standing or during simple movement tasks.

Why now?

Early adolescence is a time when LBP starts to become noticeable in the population. It is valuable to identify the differences that exist in those who are starting to develop symptoms of LBP with those who have no symptoms. This should provide a better understanding of the development of LBP in adolescence.

What will be measured?

A test battery has been developed that will investigate different aspects of motor control. It is aimed to find differences between groups of adolescents with and without LBP. The tests are mainly concerned with control of the lower back.

What equipment will be used?

We are interested in knowing what position the spine is in during most of the tests. Small sensors (Fastrak sensors) are taped to the skin over 3 vertebrae (1 on the pelvis, 2 on the low back) and the position of these sensors will be very precisely measured through the test battery using an electromagnetic field. This tracking device is not invasive, nor has it been associated with any side effects.

Setting up - The Fastrak sensors will be taped to the skin with hypoallergenic tape. The skin surface will be cleaned with alcohol prior to the attachment of the sensor.

What to wear - The researchers will need to see the trunk of the body throughout testing. For this reason it is important that subjects be in a state of semi-undress and expose their backs. A pair of shorts that can be positioned on the waist will be required and as will a crop top or bathers top. The girls dignity will be considered at all times. The research staff attaching the sensors and positioning the subject will be a qualified female physiotherapist.

What happens through the test battery - Subjects will be asked to complete a child behaviour checklist questionnaire and a Tanners Growth Staging Chart. The Child Behaviour Checklist will be evaluated by Katherine Cheng, school psychologist from Perth College. The Tanners Growth Staging chart is requested because age and physical development are often quite different during adolescence. Some girls may find this embarrassing to complete but if so, they can not complete it if they so wish. Subjects in the no LBP group will also be required to

complete a physical activity questionnaire and a back beliefs questionnaire (LBP subjects have already previously completed these). All subjects will then undertake the following; with the first three tests being repeated 2-3 times:

1. Sit unsupported on a stool in usual posture
2. Move from their usual sitting posture to slumped sitting and return
3. Move from upright sitting, flex and extend the low spine and return to upright sitting
4. Reach forward towards their toes as far as possible whilst sitting
5. Assume a semi-squat position for as long as they are able
6. Assume an unsupported trunk position face down over the edge of a bed for as long as able

Tests 5 and 6 are tests of maximal effort; they are designed to fatigue the trunk and thigh muscles. Some subjects will notice symptoms of fatigue and post-exercise soreness in these muscles for 48-72 hours. This is not expected to last or make any LBP symptoms worse.

Parents/caregivers do not have to attend the testing but are welcome if they wish to do so. Subjects and their parents/caregivers will be encouraged to ask questions as they arise through testing. Subjects will be free to withdraw from the study at any time either through their own desire or that of their parent/caregiver. The researcher will cease testing if any of the test battery aggravates or creates unwelcome symptoms for the subject. Transport will be arranged to and from the subjects' school.

Will my child's information be kept confidential?

Your child will be allocated an identification number that will remain confidential to the investigators and the project supervisor. All recorded data will be entered in an excel program, on a Curtin School of Physiotherapy computer using your identification number only, no names will be used. Access to the stored data will be restricted by a password known only by the investigators and the project supervisor. All data collected and consent forms will be stored safely in a locked cupboard at the Curtin School of Physiotherapy.

Ethical approval has been obtained for this study from the Human Research Ethics Committee of Curtin University of Technology, approval number 95/2005. It has also been approved by your school Principal.

How long will this take?

The data collection session will take approximately 1.5 hours.

How will this information be used?

This information will be analysed to determine differences between the adolescent rowers with and without LBP and provide important information to the Principals of the IGSSA schools in determining safe training, screening and crew selection methods to minimize the occurrence of LBP in rowers. It will provide valuable insight into how girls move their lower back at a critical time of development. The results of the study will be published, names or identifying information will not be published regarding any participant.

We would like you to feel free to ask any questions you may have about any aspect of the study. It is important that you understand why we are asking you to allow your child to participate in this study. The first point of contact in this regard is Ms Debra Perich, her details are below.

We would like to assure you that all information we collect is strictly confidential. Curtin University and its researchers are bound by the Privacy Act 1988 and abides by this at all times. If you have any concerns or complaints regarding the way this study is being conducted you can direct enquiries to the Secretary of the Human Research Ethics Committee Curtin University, Ms Sinead Darley on 08 9266 2784.

Thank you again for considering this important research.

Dr Angus Burnett	Dr Peter O'Sullivan	Debra Perich
Research Fellow	Senior Lecturer	Masters Student
		0409 467 449

School of Physiotherapy
Curtin University of Technology

Appendix R – Participant Information Sheet: Study II

An Examination of Low Back Pain in Schoolgirl Rowers

Dear

Thanks for thinking about being in this study. We want to know how teenagers position their bodies when they sit and also want your thoughts on Back Pain. We want to know how people who are experiencing Lower Back Pain (LBP) whilst rowing use their bodies in a variety of simple tasks and compare how this differs to those without LBP. It may not sound too exciting, but we're hoping it will provide some great information and help us understand teenage bodies with back pain better, and help us in improving our School Rowing Programs by reducing the amount of lower back pain in the sport.

What will be measured?

A series of tests has been developed that will investigate different aspects of how you position your body. Most tests look just at the low back but some look at how you use your whole body. All subjects will also be asked to complete two questionnaires:- one is a behaviour checklist and the other is to tell us what stage of physical development you are at. Those of you who do not experience LBP (the lucky ones) will also be asked to complete a physical activity questionnaire and a back beliefs questionnaire – these will take approximately 10 minutes in total.

What equipment will be used?

We are interested in knowing what position the spine is in during most of the tests. This will be measured by placing small sensors over you lower back in three locations. None of this usually creates any discomfort.

Setting up - For the movement sensor data to be collected successfully the contact between the sensor and the skin must be good. Alcohol will be used to clean the skin, sensors stick to the skin similar to a band-aid and are easily removed. The movement sensors will also be taped to the skin to minimize movement.

What to wear - We'll need to see your back through the tests. So we'll ask you to expose your back. A pair of shorts that can be positioned on the waist would be best and additionally a crop top or bathers top would be ideal. The research staff attaching the sensors and positioning your body will be a qualified female physiotherapist. We'll try as best as we can to make you feel comfortable.

This study has been approved by the Curtin University Human Research Ethics Committee. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784.

What happens through the physical test battery - You will need to the first four tests 2-3 times, we will tell what and how to do them and none of them are too hard:

1. Sit unsupported on a stool in usual posture
2. Move from their usual sitting posture to slumped sitting and return
3. Move from upright sitting, flex and extend the low spine and return to upright sitting.
4. Reach forward towards your toes as far as you can whilst sitting.
5. Assume a semi-squat position for as long as they are able
6. Assume an unsupported trunk position face down over the edge of a bed for as long as able

Tests 5 and 6 are tests of maximal effort; they are designed to fatigue (tire) the trunk and thigh muscles. Some of you will notice symptoms of tiredness and soreness in these muscles for 48-72 hours. This is not expected to last or make your LBP worse if you have any.

While we are testing you will be able to ask as many questions as you like. You can pull out at any time without any prejudice. We will cease testing if any of the tests give you unwelcome symptoms.

How long will this take?

The data collection session will take about 1.5 hours. Your parents/caregivers can accompany you if you wish or alternatively transport will be arranged from your school.

How will this information be used?

We'll see what's different between those of you with LBP whilst Rowing and those who don't. We'll prepare a report for your school Principal and the information will be used to determine safe screening, training and crew selection methods. We'll publish the results in scientific journals (magazines) but don't worry no names will be given, and no one will know you've been a part of the research. If you have any questions you are welcome to ring us, or ask your Mum, Dad or Caregiver to. Ring Debra first, her number is below.

Thank you for considering being a part of our research.

Dr Angus Burnett	Dr Peter O'Sullivan	Debra Perich
Research Fellow	Senior Lecturer	Masters Student
		0409 467 449

School of Physiotherapy

Curtin University of Technology

Appendix S – Parent Consent Form: Study II

An Examination of Low Back Pain in Schoolgirl Rowers

I, _____ have read the Parent Information Sheet explaining the study on An examination of low back pain in schoolgirl rowers . Any questions asked have been answered to my satisfaction.

Withdrawal from the study at any stage will be possible.

I agree that the research data gathered from the results of this study may be published, provided that names are not used.

I understand that it will involve:

- Completion of a Child Behaviour Checklist and Tanners Growth Staging chart
- The attachment of sensors to the skin of their back, to collect movement information
- Completion of a Physical Activity Questionnaire and a Back Beliefs Questionnaire (for those in the no LBP group only)

I agree to my daughter _____ participating in the study:

Dated _____ day of _____ 20 _____

Signed _____ (Parent/Guardian)

I, _____ have explained the above study to the signatory who states that he/she understand the same.

Signed _____ (Investigator)

Appendix T– Subject Consent Form: Study II

An Examination of Low Back Pain in Schoolgirl Rowers

I, _____ have read the Adolescent Information Sheet explaining the study on low back pain and motor control in adolescents . Any questions asked have been answered to my satisfaction.

Withdrawal from the study at any stage will be possible.

I agree that the research data gathered from the results of this study may be published, provided that names are not used.

I understand that it will involve:

- Completion of a Child Behaviour Checklist and Tanners Growth Staging chart
- The attachment of sensors to the skin of their back, to collect movement information
- Completion of a Physical Activity Questionnaire and a Back Beliefs Questionnaire (for those in the no LBP group only)

I agree to participate in the study:

Signed_____

Dated _____ day of _____ 20 _____

I, _____ have explained the above study to the signatory who states that she understand the same.

Signed _____ (Investigator)

Appendix U – Parent Information Sheet Control Group: Study III

Low Back Pain in Adolescent Female Rowers: A Multi-Disciplinary Intervention Study

A study conducted by the School of Physiotherapy, Curtin University of Technology

Rowing is one of the largest participant sports of the Independent Girls' Schools' Sports Association (IGSSA) in Western Australia with approximately 400 participants.

WHY are we conducting the study?

In 2005 research was conducted that showed that schoolgirl rowers had a LBP prevalence that was approximately three times the incidence of LBP in a matched non-rowing control group. Your daughter may have participated in this research last year. The primary aim of this research is to determine if a multi-disciplinary (physiotherapy and sports science) intervention program will reduce the incidence of LBP in schoolgirl rowers in addition to decreasing the level of pain and disability associated with LBP in adolescent girl rowers.

HOW? What do I have to do?

Participation as a subject in the control group of the study (ie no intervention) is voluntary. The series of questionnaires will take your daughter approximately 30 minutes to complete and will be issued on four separate occasions during the rowing season (approximately week 3, week 12, week 21 in addition to 10 weeks post-season). These questionnaires will include a general questionnaire to determine if your daughter experiences pain whilst rowing as well as a questionnaire describing the Level of Pain, a Modified Oswestry Questionnaire to determine level of disability related to the pain, a Fear Avoidance Questionnaire assessing movement capabilities with low back pain, and a Questionnaire asking about your daughter's belief's about back pain.

There will be no cost to you. The cost to your daughter will be her time to complete the questionnaire. There are no risks associated with participation in this research.

The benefit of participating in this study is that you and your child will help us to determine if an intervention program will decrease the prevalence of LBP amongst female adolescent rowers. Even as a subject of the control group this is an important part of the study. Information about the findings of this study and recommendations will be made available to you via your school.

What if I do not want my child to take part in the first study?

If after reading this information sheet you decide you do not want your child to participate in the study, all you need to do is to fill in the attached form titled "Request to Exclude" and return it to her school or Rowing Co-ordinator by Monday 10th April, 2006. Your child will not be prejudiced in any way by refusing to participate in this study.

If you do not fill in the 'Request to Exclude" form, your daughter will be asked to complete the questionnaires.

Will my child's information be kept confidential?

We are collecting your daughter's name so we can recognize her to match the questionnaires that she completes throughout the season. All other information collected will be anonymous.

Your child will be allocated an identification number that will remain confidential to the investigators and the project supervisor. All recorded data will be entered in a Spreadsheet excel program, on a Curtin School of Physiotherapy computer using your identification number only, no names will be used. Access to the stored data will be restricted by a password known only by the investigators and the project supervisor. All data collected and consent forms will be stored safely in a locked cupboard at the Curtin School of Physiotherapy.

Ethical approval has been obtained for this study from the Human Research Ethics Committee of Curtin University of Technology, It has also been approved by your school Principal.

What about the results of the study?

Detailed reports on the study will be published in international scientific journals. No published reports will have information that identifies any of the individual subjects. A report will also be presented to your school Principal when we have finished the study.

Has this study been approved?

This study has been approved by your Principal. Further, the study has also been approved by the Human Research Ethics Committee of Curtin University of Technology (approval number HR 15/2006).

Questions? If you have any questions, queries or problems please contact:

- Debra Perich: School Of Physiotherapy, Curtin University of Technology.

Phone: 0409 467 449, Email: deb@pc.wa.edu.au

- Or, the secretary of the Human Research Ethics Committee, Ms Linda Teasedale, Curtin University of Technology (Phone 9266 2784).

Thank you

Debra Perich

Head of Physical Education Perth College

Masters candidate

School of Physiotherapy

Curtin University Of Technology

Dr Angus Burnett

Research Fellow

School of Physiotherapy

Curtin University Of Technology

Assoc. Prof Peter O'Sullivan

School of Physiotherapy

Curtin University Of Technology

Appendix V – Parent Information Sheet Intervention Group: Study III

Low Back Pain in Adolescent Female Rowers: A Multi-Disciplinary Intervention Study

A study conducted by the School of Physiotherapy, Curtin University of Technology

Rowing is one of the largest participant sports of the Independent Girls' Schools' Sports Association (IGSSA) in Western Australia with approximately 400 participants.

WHY are we conducting the study?

In 2005 research was conducted that showed that schoolgirl rowers had a LBP prevalence that was approximately three times the incidence of LBP in a matched non-rowing control group. Your daughter may have participated in this research last year. The primary aim of this research study is to determine if a multi-disciplinary (physiotherapy and sports science) intervention program will reduce the incidence of LBP in schoolgirl rowers in addition to decreasing the level of pain and disability associated with LBP in adolescent girl rowers. At your daughter's school the rowing training program has been significantly modified from 2005 to include musculo-skeletal screening, postural education, and specific conditioning exercises. The nature of training will also change, with less long rows being included as in 2005 the girls consistently reported that this factor exacerbated their back pain.

HOW? What do I have to do?

Participation is the testing is voluntary, however your daughter will be participating in an altered rowing program within your school to that implemented during the 2005 season. As part of this study we propose that all girls undergo a musculoskeletal screening to identify factors that may be related to injury. This is widely considered as a best practice approach. This screening will be conducted by post-graduate trained and experienced Musculoskeletal and Sports Physiotherapists. With this information individual factors for each girl will be identified to allow for a specifically tailored intervention program. The cost to you will be approximately $60 and this is claimable if you have the appropriate ancillary health cover and if your daughter currently experiences LBP. After this your daughter will also undergo some LBP education as well as specific spinal-pelvic control exercises to improve spinal muscle protection and conditioning. In addition she will participate in a strength and conditioning program which will be specifically designed to increase lower limb and back muscle endurance, factors that were clearly identified as being related to the appearance if LBP in our research conducted in 2005. Although this seems at first glance that your daughter's training time will increase, it will not. It will just be re-organised.

If your daughter participates in the research she will complete a series of questionnaires that will take approximately 30 minutes to complete and will be issued on four occasions during the rowing season (week 3, week 12, week 21 and 10 weeks post-season). These questionnaires will include a general questionnaire to determine if your daughter experiences low back pain whilst

rowing as well as a questionnaire describing the Level of Pain, a Modified Oswestry Questionnaire to determine level of disability related to the pain, a Fear Avoidance Questionnaire assessing movement capabilities with low back pain, a Child Behaviour Checklist and a Back Beliefs Questionnaire. In addition she will be asked to participate in some physical testing where her usual and slump sitting posture and her flexibility of her low back and hips will be measured. Further, her lower limb and back muscle endurance will be assessed . For the usual and slump sitting posture test some reflective markers will be fixed to her body and a photograph taken with a digital camera. For the screening and these photos your daughter will need to wear her shorts and a half top or sports bra. A bather top would also be fine. These photos will be used for research purposes only and will only be accessed by members of the research team.

The cost to your daughter will be her time to complete the questionnaires and the physical tests. There are no risks associated with participation in this research.

The benefit of participating in this study is that you and your child will help us to determine if an intervention program will decrease the prevalence of LBP amongst female adolescent rowers. Information about the findings of this study and recommendations will be made available to you via your school at the completion of the study.

Will my child's information be kept confidential?

We are collecting your daughter's name so we can recognize her to match the four questionnaires that she completes throughout the season. All other information collected will be anonymous.

Your child will be allocated an identification number that will remain confidential to the investigators and the project supervisor. All recorded data will be entered in a Spreadsheet excel program, on a Curtin School of Physiotherapy computer using your identification number only, no names will be used. Access to the stored data will be restricted by a password known only by the investigators and the project supervisor. All data collected and consent forms will be stored safely in a locked cupboard at the Curtin School of Physiotherapy.

Ethical approval has been obtained for this study from the Human Research Ethics Committee of Curtin University of Technology. It has also been approved by your school Principal.

How will this information be used?

The information will be analysed to determine if a multi-disciplinary intervention program decreases the incidence of LBP and will provide important information to the Principals of the IGSSA schools in determining safe training and screening methods to minimize the occurrence of LBP in rowers. The results of the study the study will be published in international scientific journals. No published reports will have information that identifies any of the individual subjects. A report will also be presented to your school Principal when we have finished the study.

We would like you to feel free to ask any questions you may have about any aspect of the study. It is important that you understand why we are asking you to allow your child to participate in this study. The first point of contact in this regard is Ms Debra Perich and her details are below.

We would like to assure you that all information we collect is strictly confidential. Curtin University and its researchers are bound by the Privacy Act 1988 and abides by this at all times. If you have any concerns or complaints regarding the way this study is being conducted you can direct enquires to the Secretary of the Human Research Ethics Committee Curtin University, Ms Linda Teasedale on 08 9266 2784. (approval number HR 15/2006).

Thank you once again for considering this important research.

Dr Angus Burnett

Research Fellow

School of Physiotherapy

Curtin University Of Technology

Assoc Prof Peter O'Sullivan

School of Physiotherapy

Curtin University Of Technology

Debra Perich

Head of Physical Education Perth College

Masters candidate

School of Physiotherapy

Curtin University Of Technology

Appendix W – Participant Information Form Control Group: Study III

Low Back Pain in Adolescent Female Rowers: A Multi-Disciplinary Intervention Study

A study conducted by the School of Physiotherapy, Curtin University of Technology

Dear

In 2005 some research was conducted that determined that the incidence of Low Back Pain amongst Schoolgirl Rowers was three times more prevalent than when compared with schoolgirls who do not row.

We are trying to work out if changing some of the training techniques alters the prevalence of back pain.

Thanks for thinking about being in this study

What will be measured?

A series of questionnaires have been developed that will investigate the prevalence of back pain, levels of pain and disability that you are experiencing, and your beliefs on pain.

What is involved and how long will it take?

As part of being a member of the control group (that means no intervention) you will be required to complete 5 questionnaires that will take approximately 30 minutes of your time. These will be provided to you 4 times during the season.

While we are testing you will be able to ask as many questions as you like. You can pull out at any time without having to give a reason and without any penalties.

How will this information be used?

We'll see if the number of you experiencing LBP will decrease when a special training program is put in place. We'll provide a report for your school Principal and publish the results in scientific journals (magazines) but don't worry, no names will be given and no one but the researchers will know you've been a part of the research. We might be able to decrease the amount of pain experienced whilst rowing and make the sport more enjoyable for all of you who participate.

If you have any questions you are welcome to ring us, or ask your Mum, Dad or Caregiver to. Ring Debra first, her number is below.

Dr Angus Burnett
Research Fellow
School of Physiotherapy
Curtin University Of Technology

Assoc Prof Peter O'Sullivan
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Debra Perich
Head of Physical Education Perth College
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Appendix X - Participant Information Form Intervention Group: Study III

Low Back Pain in Adolescent Female Rowers: A Multi-Disciplinary Intervention Study

A study conducted by the School of Physiotherapy, Curtin University of Technology

Dear

In 2005 some research was conducted that determined that the incidence of Low Back Pain amongst Schoolgirl Rowers was three times more prevalent than when compared with schoolgirls who do not row.

We are trying to work out if changing some of the training techniques alters the prevalence of back pain. Your school has changed many things in the training program from that of the 2005 season. You will undergo a musculoskeletal screening that will identify things about your posture that may increase your risk of low back pain when rowing. This approach is widely used when kids of your age start elite rowing programs. With this information you will be given specific posture exercises for you to do. It is important that you do these if you agree to participate in this study as they are designed to help you. Also, you will be required to attend an education session about low back pain. This session will include factors that cause low back pain and things that you can do to lessen the possibility of getting it. Also you be doing strength and conditioning sessions during rowing training, that are designed to increase your lower limb endurance and back muscle endurance.

When you are screened you will need to wear your shorts and a half top or sports bra. A bather top would also be fine. This will help the physiotherapist do a thorough screening and design a program for you.

Thanks for thinking about being in this study.

What else will be measured?

A series of questionnaires have been developed that will investigate the prevalence of back pain, levels of pain and disability that you are experiencing, child behaviours and your beliefs on back pain. Your usual and slump sitting positions will also be measured as well as your lower limb and back muscle endurance and your flexibility in a sit and reach test. To measure your usual and slump sitting postures seven reflective markers will be placed on landmarks on the right side of your body and then a camera will record your joint angles. These pictures will be used for nothing else but to examine your posture and will be only viewed by the researchers in this study.

What is involved and how long will it take?

You will be required to complete 5 questionnaires that will take approximately 30 minutes of your time and these will be given to at 4 times during the season. You will also complete the physical tests on 2 occasions during the season and it will take you approx 30 minutes each time.

While we are testing you will be able to ask as many questions as you like. You can pull out at any time without having to give a reason and without any penalties.

How will this information be used?

We'll see if the number of you experiencing LBP will decrease when a special training program is put in place. We'll provide a report for your school Principal and publish the results in scientific journals (magazines) but don't worry, no names will be given and no one but the researchers will know you've been a part of the research. We are wanting to decrease the amount of pain experienced whilst rowing and make the sport more enjoyable for all of you who participate.

If you have any questions you are welcome to ring us, or ask your Mum, Dad or Caregiver to. Ring Debra first, her number is below.

Dr Angus Burnett
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Assoc Prof Peter O'Sullivan
School of Physiotherapy
Curtin University Of Technology

Debra Perich
Head of Physical Education Perth College
Masters Candidate
School of Physiotherapy
Curtin University Of Technology
0409 467 449

Appendix Y – Request to Exclude: Study III

Low Back Pain in Adolescent Female Rowers: A Multi-Disciplinary Intervention Study

A study conducted by the School of Physiotherapy, Curtin University of Technology

We request that our daughter

_____

(Name)

in _____

(Year)

at _____

(School)

be <u>excluded</u> from this study.

We understand that our daughter will not be prejudiced in any way for not participating.

Name (parent / guardian)_____

Signature_____

Date_____

Appendix Z – Document of Informed Consent: Study III

Curtin University of Technology

School of Physiotherapy

Document of Informed Consent

Low Back Pain in Adolescent Female Rowers: A Multi-Disciplinary Intervention Study

I _____ have read all of the information contained on this sheet, and have discussed it with my daughter, and have had all questions relating to the study answered to my satisfaction.

I agree for my daughter to participate in this study and understand that she is free to withdraw at any time, for any reason without prejudice.

I agree that the research data obtained from this study may be published. I understand that my daughter will not be identifiable in any way as a process of this study.

Name of participant:_____

Parent/guardian signature:_____ Date:_____

Investigator:_____ Date:_____