Title: A comparison of isolated lumbar extension strength between healthy asymptomatic participants and chronic low back pain subjects without previous lumbar spine surgery

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1.0 Introduction

Low back pain (LBP) affects 60-80% of adults at some time in their life [1]. Many will recover in the acute stages without intervention, though a considerable proportion develop chronic LBP (CLBP) [2,3]. The high recurrence rates of CLBP has resulted in increasing numbers undergoing surgery. Kalakoti et al[4] reported an increase of 60.5% in primary lumbar spine fusion surgeries in the United States between 2002 and 2009. It is also estimated that 27% of hospital admissions for LBP in England undergo surgical intervention[5]. Not only are direct treatment costs including the costs of surgery considerable, but the indirect costs due to productivity losses are also vast[6]. As such, a primary focus of research has been upon the factors associated with LBP that could be targets of potential preventative or therapeutic interventions.

Deconditioning of the lumbar extensor musculature is suggested to be a risk factor for low back injury and pain[7-9]. In fact, a recent review concluded that, in general, evidence supports the role of deconditioning in CLBP[10]. However, the authors noted a number of methodological concerns with the present literature. For example, numerous testing methods exist to examine lumbo-pelvic complex function in extension. Broadly they can be generalised into tests examining trunk extension (TEX), involving both hip and lumbar extension, and isolated lumbar extension (ILEX), where the pelvis is restrained and the hips unable to contribute to torque development. Indeed, there is poor association between outcomes from these two testing approaches suggesting that they measure different components of lumbo-pelvic function[11].

In their review, Steele et al[10] separated studies utilising TEX and ILEX focusing on interpretation of the latter as a more specific measure of the function (strength/endurance) of the lumbar extensor musculature. A number of studies suggested participants with CLBP had significantly lower ILEX strength compared to healthy asymptomatic controls[12-18] with one exception[19]. However, Steele et al[10] also noted several methodological concerns with these studies including; low participant numbers[12-14,17-19], lack of statistical comparisons between CLBP and asymptomatic groups[15-18], and finally, inclusion of CLBP participants with previous surgery[12,14], or lack of specification as to whether prior surgery was an exclusion criteria[13,15-18]. The latter is of particular concern considering the prevalence of surgical intervention in CLBP. There is consistent evidence that posterior spine surgery often results

in deconditioning of the lumbar extensor musculature, causing loss of muscle density, histological changes, and also decreased strength[20-23]. Therefore, it is apparent that previous surgery may have implications for the results of studies examining the deconditioning hypothesis and ideally larger studies of participants with prior surgery excluded should be conducted[10].

The one study that did control for surgery of the pelvis or spinal column[19] does not support the presence of lumbar extensor deconditioning (i.e. ILEX weakness) in CLBP participants. Lariviere et al[19] reported age, stature and body mass were all similar between their groups suggesting lack of control of prior surgery in previous studies may have influenced the reported differences between groups. However, Cassisi et al[12] compared between CLBP participants with (*n* = 13) and without (*n* = 8) prior surgery in their study and found no difference in ILEX strength. Further, there is consistent evidence of deconditioning using *in vitro* and *in vivo* methods such as biopsy and imaging where surgery has been controlled for[10]. As such, it is unclear whether a difference in ILEX strength does exist between those with and without CLBP when controlling for prior surgery, particularly due to small sample sizes.

Prior studies examining lumbar extensor muscle function between those with and without CLBP suffer from a number of methodological issues. Most prominently, these include inappropriate tests for lumbar extensor function (i.e. TEX tests), low sample size, lack of statistical comparisons, and lack of consideration for the effects of prior surgery. Therefore, the aim of this study was to examine lumbar extensor function between CLBP and asymptomatic control participants using an ILEX form of testing. This study also aimed to recruit a greater sample size than previous studies whilst controlling for prior surgery.

2.0 Methodology

2.1 Research Design

A cross sectional study design was adopted with one asymptomatic control group and one CLBP group, in order to compare ILEX strength between the two groups. The study was approved by the Centre for Health, Exercise and Sport Science ethics committee (ID No: 416) at the first author's institution, and was conducted within the Sport Science Laboratories. Prior to testing, all participants were provided with a participant information sheet, detailing

what would be asked of them as well as their right to withdraw and were then required to sign an informed consent form.

2.2 Participants

Forty-two healthy asymptomatic (25 males and 17 females) formed the control group, and 53 participants with non-specific CLBP (30 males and 23 females) aged between 19 and 76 years were recruited on a voluntary basis. This was a sample of convenience, with participants being recruited via email, adverts, social media, and word of mouth. Inclusion criteria for participants with CLBP were as follows: nonspecific CLBP occurring almost daily for at least 12 weeks, and no medical conditions for which a maximal effort test was contraindicated. Exclusion criteria for the asymptomatic group was back pain exceeding one week in the preceding year. General exclusion criteria were as follows: pregnancy, sciatica, pain radiating below the knee, disc herniation, vertebral fractures, other major structure abnormalities and surgery of the pelvis or spinal column. All CLBP were assessed by a manual therapist (Physio or Chiropractor) to confirm their suitability for inclusion into the study.

2.3 Instrumentation

Stature was measured using a stadiometer (Holtan ltd, Crymych, Dyfed, UK), body mass was measured using scales (Seca, Hamburg, Germany). Mass, stature and body mass index were similar in both asymptomatic and symptomatic participants (Table 1). Isometric strength testing for ILEX was performed using the MedX Lumbar Extension Machine (MedX, Ocala, FL, USA; Figure 1). This equipment has been found to be highly reliable through a 72-degree range of motion (ROM) of lumbar extension in asymptomatic participants (r = 0.81-0.97)[24] and symptomatic participants (r = 0.57-0.93)[25]. The Oswestry Disability Index (ODI) version 2.0 was used to assess disability and has been shown to be a valid and rigorous measure of condition-specific disability[26]. A 100-mm Visual Analogue Scale (VAS) was used to measure pain rating in CLBP participants[27].

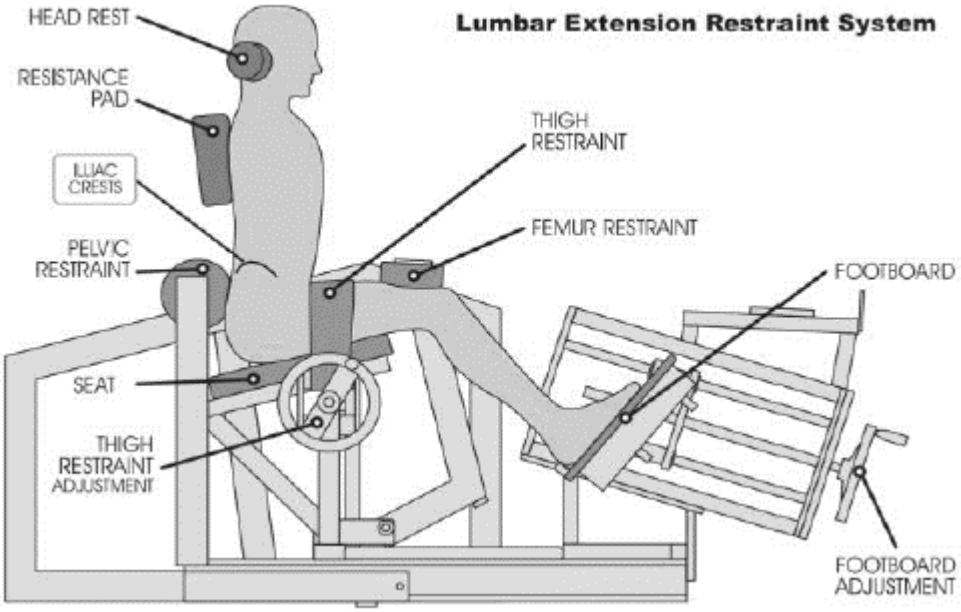

Figure 1. MedX schematic demonstrating the restraint system, thus isolating lumbar extensors (Reproduced with permission from MedX Corporation).

2.4 Procedures

A Physical Activity Readiness Questionnaire (PARQ) was completed to screen for contraindications and confirm suitability based on inclusion and exclusion criteria. The participants visited the laboratory for testing on two separate occasions at least 72 hours apart. The first testing day included the collection of anthropometric data and a familiarisation session for ILEX testing. On the second testing day, participants completed the ODI and VAS and underwent a further ILEX test. Each test involved maximal voluntary isometric contractions at various angles through the participant's full ROM. Briefly, after an initial light warmup and practice test at 50% of maximal perceived effort, participants performed isometric contractions where they increased effort gradually over a 3 second period until maximal. The restraint system was designed to prevent pelvic movement so that ILEX function could be tested independently. Details of the full-test protocol and its restraint system (figure 1) have previously been documented elsewhere[24].

2.5 Data Analysis

ILEX strength, reported as a strength index (SI; calculated as the area under the curve of all angles tested using the trapezoidal method), was measured in foot pounds (ft-lbs) and converted to newton metres (N·m). Results from the testing were analysed using JASP (version 0.8.2) computer software, with an alpha level of 0.05 set as the level of statistical significance. The Shapiro-Wilk test was used to examine assumptions of normality of distributions as research has shown it to be the most powerful test for all types of distributions and sample sizes[29]. Following the Shapiro-Wilk test, demographic data was examined for between group differences using an independent *t*-test for normally distributed data and a Mann-Whitney U for data which was not normally distributed. Post-hoc effect sizes were calculated and were interpreted as low (0.20 to 0.50), moderate (0.50-0.80), or large (>0.80)[30].

3.0 Results

3.1 Participants

Participant demographics are shown in Table 1. An independent *t*-test was conducted on the normally distributed data, which revealed no significant differences between the groups for either stature ($t_{(93)}$ = 0.834, p = 0.406) or body mass ($t_{(93)}$ = -0.425, p = 0.672). Age, BMI and

ROM were not normally distributed and so a Mann-Whitney U test was carried out on these variables. This revealed no significant differences between the two groups for BMI (Z = 941.00, p = 0.199) or ROM (Z = 1282.50, p = 0.176), though age was significantly greater in the CLBP group (Z = 755.00, p = 0.007). The results from the ODI classified the CLBP participants as having moderate disability.

Table 1. Participant Demographics and Descriptive Statistics

Characteristic	CLBP (n= 53)	NCLBP (n= 42)
Sex Ratio (M:F)	1.30:1.00	1.47:1.00
Age (year)	39 ± 15	30 ± 12
Stature (cm)	171.71 ± 9.66	173.43 ± 10.40
Mass (kg)	75.73 ± 14.16	74.54 ±12.53
BMI (kg/m^2)	25.59 ± 3.79	24.75 ± 3.46
Lumbar ROM (˚)	65.38 ± 8.71	68.26 ± 5.10
VAS (mm)	35.53 ± 21.06	NA
ODI (%)	24.51 ± 11.00	NA

Results are mean ± SD. BMI: Body Mass Index; VAS: Visual Analogue Scale; ODI: Oswestry Disability Index; NA: Not applicable.

3.2 Isolated Lumbar Extension Strength

The results from the Mann Whitney U test indicated that ILEX strength was significantly greater in the asymptomatic group compared to the CLBP group (Z = 1441.00, p = 0.014). Figure 1 shows a descriptive plot of the data with 95% confidence intervals. Post-hoc effect size was calculated to be d = 0.56, showing a moderate effect.

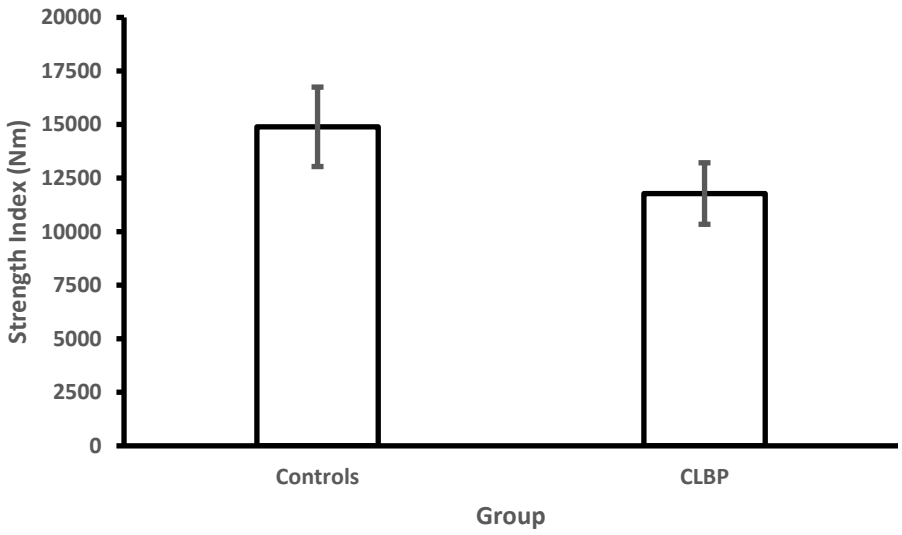

Figure 1. Descriptive plot of strength index values (mean±95%CI) in controls and CLBP participants.

4.0 Discussion

The aim of this study was to investigate the differences in ILEX strength between CLBP and asymptomatic control participants without a history of spinal surgery. Statistical analysis revealed that there was a significant difference between the two groups (p = 0.014), with the asymptomatic group demonstrating a larger SI compared to the CLBP group. Studies employing an ILEX method of testing are relatively scarce; however, there are several studies in agreement with this finding[12-18]. Further, the present study also controlled for the presence of prior surgery in a sample size that is larger than previous studies, and still identified the presence of ILEX weakness in CLBP participants compared with healthy asymptomatic controls.

Most prior studies examining ILEX differences between participants with and without CLBP have not controlled for the presence of prior surgery and this may be a possible reason for the reported ILEX weakness in CLBP populations. However, Lariviere et al[19] controlled for the presences of prior surgery and found no significant difference in ILEX strength or endurance between participants with (n = 18) and without CLBP (n = 18). ILEX strength was defined as peak isometric torque at a single test angle, and endurance consisted of repetitions performed to momentary failure at 60% of their maximal torque. It was reported that age, stature and body mass were all similar between the groups in addition to the sex ratios

between groups. This implies that the control of surgery may have been a confounding factor for differences in results within this investigation.

There is consistent evidence that posterior spine surgery results in deconditioning of the lumbar extensor musculature, causing loss of muscle density and thus potentially decreased strength[20-23]. Therefore, the results of prior studies indicating a difference in ILEX strength between those with and without CLBP may have been influenced by the presence of participants having undergone previous lumbar surgery. However, in review, Steele et al[10] note that imaging studies show the presence of lumbar extensor atrophy, and studies using electromyography show greater fatigability, in persons with CLBP even when controlling for the presence of prior lumbar surgery. The findings from these studies suggest that atrophy of the lumbar extensors may in fact be present independent of previous lumbar surgery.

Perhaps a more logical explanation for the lack of difference between the two groups in the study of Lariviere et al[19] is the relatively small sample size. As such, the lack of significant difference may have been due to their CLBP group not being reflective of the typical heterogeneity seen in this population. Indeed, it is possible that sampling error resulted in a number of unusually strong CLBP participants. In comparison the present study had almost three times as many participants and therefore likely was better representative of the typical CLBP population in addition to being more powered to detect differences.

The presence of lumbar extensor deconditioning might suggest that a specific approach to exercise for this musculature might be appropriate as both a preventative[31] and therapeutic approach[32] for CLBP. However, despite *in vivo* evidence (e.g. imaging and electromyography studies) suggesting the presence of muscular deconditioning, it is unclear as to whether decreased function in the form of ILEX weakness is due to deconditioning of the lumbar extensors, or other factors such as pain avoidance behaviours and lack of motivation. Indeed, in early studies this was the primary explanation for the apparent weakness in extension in persons with CLBP[33]. For example, Holmes et al[13] showed that prior to an ILEX resistance training intervention, a group of geriatric females with CLBP were significantly weaker than a comparative healthy geriatric female asymptomatic control group. After the intervention, however, there was no longer a significant difference between the two groups. This implies

that atrophy was present prior to intervention, perhaps resulting in significantly weaker lumbar extensors and that the ILEX exercise was effective at targeting specifically the lumbar extensors. However, these improvements may have also been a result of alterations to pain related behaviours. For instance, Risch et al[34] reported that ILEX resistance training can also improve psychological factors, including a reduction in pain and improved perceptions of physical and psychological functioning. Al-Obaidi et al[35] also found that anticipation of pain was the greatest predictor of isometric strength deficits in CLBP participants.

Changes to pain related behaviours may provide part of the explanation for the reduced ILEX strength in CLBP participants. However, as stated previously, *in vivo* studies have provided evidence of deconditioning of the lumbar musculature, whilst controlling for prior surgery. Therefore, it is likely that there are both physical and psychological factors affecting ILEX strength in CLBP participants. As deconditioning is likely present whether surgery has occurred or not, it seems that specific approaches to reversing this deconditioning and loss of function, whether due to physical or psychological mechanisms, may be appropriate. Indeed, specific ILEX resistance training is likely best for specifically conditioning the lumbar extensor musculature[32], and interventions using ILEX resistance training have consistently shown significantly and clinically meaningful improvements in pain and disability in persons with CLBP[33].

4.1 Limitations and Future Research

One limitation in the present study was the significant difference in mean age between the two groups. It was reported that age, stature and body mass were all similar in the study of Lariviere et al[19] and so the different findings between this study and theirs may have been influenced by age differences. However, previous research suggests that age accounts for only a small amount of variance in lumbar dynamometry parameters in CLBP participants[37]. Further, the difference in age between the two groups (~9 years) was likely not sufficient to confound ILEX strength comparisons.

Ford et al[37,38] state that classification of LBP needs to be improved as there is a false assumption that LBP participants are a homogenous group. Therefore, implementing subgroups may help to provide greater insight into the role of lumbar extensor deconditioning

in CLBP. For example, recent work has shown that there is true inter-individual (i.e. between participants) responses to ILEX resistance training interventions in persons with CLBP[39]. This may be the result of some sub groups of persons with CLBP having a greater degree of deconditioning present initially. The identification of characteristics of CLBP sub groups, and further the identification of whether such factors are prognostic of successful outcomes is an avenue for future research.

4.2 Conclusion

The aim of this study was to investigate the differences in ILEX strength in participants with and without CLBP whilst controlling for the presences of prior surgery. Subjects with CLBP had significantly weaker ILEX strength compared with asymptomatic controls. These findings suggest that ILEX weakness and lumbar extensor deconditioning is present independent of surgery and may be a factor involved in CLBP. As such, lumbar extensor deconditioning would appear to be a reasonable target for interventions in CLBP.

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