A Review of the Clinical Value of Isolated Lumbar Extension Resistance Training for Chronic Low Back Pain

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CONTRIBUTORSHIP STATEMENT

All listed authors contributions include the conception and design, acquisition of data or analysis and interpretation of data, drafting the article or revising it critically for important intellectual content, and final approval of the version published. Regarding responsibility for overall content, the lead author, James Steele, is the guarantor.

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ABSTRACT

Objective: Chronic low back pain (CLBP) is prevalent, costly, and acknowledged as multifactorial in nature. However, deconditioning of the lumbar extensor musculature may be a common factor. Thus specific resistance exercise is often recommended. Many resistance exercises for the lumbar extensors exist though recent evidence suggests isolated lumbar extension (ILEX) resistance training may best condition these muscles. Thus this review aimed to examine use of ILEX resistance training in participants with CLBP to provide a best evidence synthesis for practitioners and clinicians.

Type: Mixed review.

Literature Survey: Previous reviews' reference lists were searched in addition to SPORTDiscus, PubMed and Google Scholar databases up to May 2014 utilising search terms including combinations and synonyms of 'isolation' 'lumbar extension' 'lumbar exercise' 'lumbar strength' 'lumbar endurance' 'lumbar spine' 'low back exercise' 'CLBP' 'pain' 'disability.'

Methodology: A 'snowballing' style literature search was utilised involving an emergent approach. Studies examining ILEX resistance training as an intervention in symptomatic CLBP populations reporting pain, disability or global perceived outcomes (GPO) as outcomes were examined. Pain and disability were outcomes were compared to consensus guidelines for minimal clinically important changes. Single case reports were excluded.

Synthesis: Results suggest ILEX resistance training produces significant and meaningful improvements in perceived pain, disability and GPOs, as part of a multiple intervention or stand-alone approach. A low frequency (1x/week) yet high intensity of effort (to momentary muscular failure) approach using either full or limited range of motion ILEX resistance training appears sufficient and best for significant and meaningful outcomes. Limited comparative studies between ILEX resistance training and other specific exercise approaches exist; however, limited evidence supports ILEX resistance training as more effective.

Conclusions: These findings highlight ILEX resistance training as effective for significant and meaningful improvements in perceived pain, disability and GPOs for CLBP participants. Further research should elucidate comparisons between ILEX resistance training and other specific exercise approaches and clarify whether lumbar extensor conditioning is the mechanism responsible for the improvements reported.

KEY WORDS: Lumbar Extension; Disability; Rehabilitation; Resistance Training

INTRODUCTION

Chronic low back pain (CLBP) is one of the most prevalent medical disorders in today's societies [1-5] representing a total economic cost amounting to billions worldwide [5-14]. Although CLBP is acknowledged as a multifactorial condition [15,16] it has been suggested that specific deconditioned extensor muscles of the lumbar spine (lumbar extensor musculature i.e. thoracic and lumbar erector spinae, including the iliocostalis lumborum and longissimus thoracis, the multifidus and also quadratus lumborum when contracted bilaterally) are a risk factor for low back injury and pain [17-20]. Indeed a recent review of the area concluded that persons with CLBP generally present with deconditioning of these muscles identified as reduced lumbar extension strength/endurance, atrophy, and excessive fatigability and that these may be risk factors for low back injury and pain [21].

Historically, progressive resistance exercise has been recommended for CLBP with the purpose of conditioning the musculature (i.e. developing strength, endurance and hypertrophy) [19,20,22,23]. The first attempts at providing therapeutic resistance exercise in treating musculoskeletal conditions occurred around the turn of the 20th century [24,25]. Despite this, mainstream acceptance of progressive resistance exercise was not achieved until around the 1940s by DeLorme and Watkins [22,23]. They reported use of specialised equipment used to address the lumbar extensor musculature by attempting to restrict concurrent pelvic movement and found with increasing strength, symptoms of CLBP were relieved [22]. The use of progressive resistance exercise historically in treating musculoskeletal disorders such as CLBP [19,20,22,23], as well as the suggested role of lumbar extensor deconditioning in low back injury and pain [17-21] has resulted in development of more specific devices for exercising the lumbar extensors. A number of devices exist commercially (e.g. Lumbar Extension Machine, MedX, Ocala, Florida; BackUp Dynamometer, Priority One Equipment, Grand Junction, Colorado; Lower Back Revival System, OriGENE Concepts BV, Delft, the Netherlands), and others have developed customized seats and restraints to use with generic dynamometers [26,27]. All provide isolated lumbar extension (ILEX) through their unique method of restraining the pelvis. The necessary features for achieving ILEX have been described previously [20,28]. However, figure 1 presents the restraint system considered as necessary for isolation of lumbar extension. The mechanism of the restraint system should be considered for its ability to specifically isolate and exercise the lumbar extensors. Indeed it has been suggested for some time that specific exercise must be isolated to effectively address the lumbar extensor musculature [17-20,22].

However, when exercise is typically examined in relation to CLBP, the varied and different approaches available are often considered in the same category and as being equal [29,30]. Specific deconditioning of the lumbar extensor musculature may be an important factor [21] and thus it is unlikely that all exercise programs are equally effective in addressing CLBP [29-31]. Both Helmhout et al [31] and Mayer et al. [29] emphasise the issue with many previous reviews examining ‘exercise’ as a single class of treatment without consideration of the variation in exercise approaches that have been used. Many studies of exercise have also been criticised as lacking an adequate description of the precise exercises used [30,31]. Previous Cochrane reviews have not adequately described, defined and categorised the ‘exercise’ studies they have examined, potentially explaining the generally inauspicious conclusions drawn [32,33]. The Cochrane reviews have been specifically criticised for this flaw and wide-sweeping conclusions [33-35]. In a recent meta-regression the authors noted firstly that exercise type may be an important factor that explains the heterogeneity between ‘exercise’ studies, yet due to limitation of the methodology used were unable to analyse the trials included based upon differences in this characteristic [36]. This issue of specificity of exercise type has also been discussed more recently and continues to be suggested as a potentially important factor to consider [37,38].

Despite the proposed importance of such specificity in exercise type the necessity of devices to isolate the lumbar extensors for the purposes of specifically conditioning them, and particularly for use in treatment of CLBP, is at present controversial. Many specific exercise approaches for the lumbar extensors have been defined and presented by Mayer et al. [29]. These are considered to be exercises designed to specifically address and condition the lumbar extensors and include; benches and roman chair trunk extensions (TEX), free weights (i.e. deadlifts, squats, good mornings etc.), floor and stability ball exercise (i.e. TEX, bridging, four-point kneeling etc.), and resistance machines including those with and without restraints capable of providing ILEX. However, a recent review has examined the efficacy of these exercises concluding that, though many may offer some degree of lumbar extensor conditioning, ILEX resistance training appears to be most effective for this purpose [28]. Considering the potential role of specific lumbar extensor deconditioning in CLBP [21] it is of interest to review the efficacy of ILEX resistance training in symptomatic populations as it appears to be an approach potentially most effective in addressing this specific factor. Thus the aim was to conduct a mixed review to search and appraise the literature examining the use of ILEX resistance training in participants with CLBP in order to provide a best evidence synthesis for practitioners and clinicians. The intention was to consider 1) studies examining ILEX resistance training’s efficacy in this population upon perceived pain, disability and global perceived outcomes

(GPO) including the clinical meaningfulness of these outcomes, 2) the manipulation of ILEX resistance training variables for best outcome such as to provide recommendations for clinical prescription, 3) and to examine comparative studies of ILEX resistance training and other specific exercise approaches[a], including use of ILEX resistance training as part of a multiple or single intervention approach.

METHODS

Previous reviews' [19,20,29,39] reference lists were searched in addition to SPORTDiscus, PubMed and Google Scholar databases up to May 2014 utilising search terms including combinations and synonyms of 'isolation' 'lumbar extension' 'lumbar exercise' 'lumbar strength' 'lumbar endurance' 'lumbar spine' 'low back exercise' 'CLBP' 'pain' 'disability.' A 'snowballing' style literature search [40] was utilised involving an emergent approach as the search progressed including searching references of references and utilising personal contact with authors and colleagues knowledgeable in the area. Broadly, any studies examining ILEX resistance training as an intervention in symptomatic CLBP populations reporting pain, disability or GPOs as outcomes were examined. Single case reports were excluded.

RESULTS

Table 1 presents a summary of all the identified studies utilising ILEX resistance training that were located and considered in this review.

Pain, Disability and Clinical Meaningfulness of Outcomes

The most common measurement of pain is the visual analogue scale (VAS [41]). Several studies have examined the use of ILEX resistance training upon perceptions of pain through this measurement. Many have been designed as prospective single arm trials of symptomatic participants with intervention periods of 8 to 12 weeks and training frequencies of 1 to 2x/week [42-45]. Samples sizes ranged from 18 to 55 participants indicating sufficient power to detect significant changes in VAS [46] with all reporting significant reductions [42-45]. Other studies have adopted randomised controlled trial designs utilising a non-training control group comparison to confirm the treatment effect from including ILEX resistance training as an intervention [46-51]. These studies used

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[a] When referring to specific exercise in this review we are referring to those defined by Mayer et al. [29]. However, a currently standard exercise approach used in addressing CLBP is that of training motor control and the neuromuscular system, which is sometimes referred to as being 'specific' in the sense of training a specific movement. Therefore, to reiterate and clarify for readers of this review in order to avoid confusion, 'specific' exercise in this review refers to exercise approaches designed to specifically target and condition the lumbar extensor musculature and not to motor control based approaches aimed at training the neuromuscular system.

interventions of ~12 to 24 weeks with varying frequencies of 1 to 2x/week and sample sizes ranging from 14 to 74 participants again suggesting sufficient power. All reported that, compared with the non-training control groups, the groups performing ILEX resistance training made significant reductions in VAS [46-51]. Control groups in these studies were either instructed to perform home based exercise [47] continue with any conservative treatments they were already undergoing [46,48-50] or acted as waiting list controls [51]. A study by Kim et al. [52] examined the effects of varying frequency of ILEX resistance training over 12 weeks upon 40 participants undergoing lumbar discectomy. They reported significant improvement in VAS for ILEX resistance training when training 1 or 2x/week.

Other methods of measurement have also been used to examine the effects of ILEX resistance training upon pain. In a randomised controlled trial of 54 participants Risch et al. [53] showed significant improvement as a result of 10 weeks of ILEX resistance training in the pain subscale on the West Haven Yale Multidimensional Pain Inventory when compared to a waiting-list control group. In a large single arm trial involving outcomes from 677 participants who underwent ~9 weeks of ILEX resistance training 2x/week, Nelson et al. [54] reported participant low back pain and leg pain outcomes using a 5 item scale (‘worse,’ ‘no change,’ ‘slight decrease,’ ‘decreased,’ ‘substantial decrease’). For low back pain and leg pain respectively, 64% and 62% reported substantial decrease, 14% and 17% reported a decrease, 6% and 6% reported a slight decrease, 12% and 13% reported no change, and only 3% and 2% reported a worsening of their symptoms. There was a moderate but significant correlation between the improvements in lumbar extension strength and low back pain (r = -0.318) and this relationship appeared even more pronounced when participants were grouped based upon the above categories. Steele et al. [46] also reported significant relationships between improvements in lumbar extension strength and low back pain (VAS) as a result of ILEX resistance training (r = -0.488 to -0.668). Another single arm trial conducted by Leggett et al. [55] across two independent treatment centres showed significant improvements in the pain subscale of the Short Form 36 health questionnaire (SF36; the SF36 is a common outcome that covers a wide range of possible subscales thus presenting an overall ‘global picture’ of participant well-being). Costa [56] in a small study involving 9 participants used the McGill Pain Questionnaire and reported a non-significant improvement (-3.22, p = 0.159) which would appear, in light of other research showing significant improvements in pain, perhaps a result of low study power. Stephan et al. (51) examined the effects of ILEX resistance training upon pain severity and effects of pain using the Medical Outcome Scale reporting significant improvements at both 3 and 6 months stage of the intervention compared with a waiting list control.

Measures of perceived disability, such as the Oswestry Disability Index (ODI) [57] amongst others have also been measured in response to ILEX resistance training interventions. Mooney et al. [42] showed a significant improvement in ODI score between pre and post measures for 55 participants undergoing 8 weeks of ILEX resistance training 2x/week. Other single arm trials have also reported significant improvements in ODI including Costa [56] (in contrast the lack of significant results for the McGill Pain Questionnaire), and Carlson & Mackay [58] over a 6 week intervention of ILEX resistance training 2x/week for 55 participants. Randomised controlled trials again have examined this effect on ODI scores as a result of the intervention in comparison to non-training controls for ~12 to 24 week interventions of ILEX resistance training 1 and 2x/week with samples ranging 24 to 74 participants [4,48-51]. Again these studies are sufficiently powered to detect changes in ODI [46] with all showing significant reductions. It was also reported that significant relationships exist between improvements in lumbar extension strength and disability (r = -0.414 to -0.539 [46]). Choi et al. [47] noted a non-significant improvement in ODI score that favoured the use of ILEX resistance training compared with non-training controls in post-surgery lumbar discectomy participants; however p values were not reported. Kim et al. [52] also demonstrated significant improvement in ODI from 12 weeks of ILEX resistance training 2x/week for participants undergoing lumbar discectomy.

Other measures of self-reported disability demonstrate similar results. In single arm trials Al-Obaidi et al. [59] showed significant improvement in overall group mean between pre and post measures using the Roland Morris Disability Questionnaire (RMDQ) for 42 participants undergoing 10 weeks of ILEX resistance training 1x/week, as did Willemink et al. [60] for 20 participants undergoing ~24 weeks of ILEX resistance training at a variable frequency. Willemink et al. [60] however also examined change in multifidus cross sectional area reporting no change. Randomised controlled trials have also examined the RMDQ. Helmhout et al., [61,62] Harts et al. [63] reported significant improvements in RMDQ in trials of 65 to 107 participants examining 8 to 10 weeks of ILEX resistance training 1 to 2x/week. These studies also compared both heavy and light load ILEX resistance training, waiting list controls and regular physiotherapy which are detailed further below. Risch et al. [53] also examined the perceived psychological and psychosocial effects of strengthening using ILEX resistance training compared with a non-training control group. Both subscales of the Sickness Impact Profile (Physical and Psychosocial Dysfunction) showed significant improvement as result of the ILEX resistance training intervention. These improvements in perceived dysfunction occurred without any change in psychological variables such as anxiety and stress. Park et al. [43] also reported a spontaneous increase in daily activity levels as a result of 8 weeks of ILEX resistance training 2x/week which suggested reduced disability or greater willingness to be active.

In terms of GPOs differing approaches have been reported. Nelson et al. [54] asked participants to either rate the perceived effectiveness of the ILEX resistance training intervention as ‘excellent,’ ‘good,’ ‘fair’ or ‘poor’ which were rated respectively as 46%, 30%, 14% and 8%. Leggett et al. [55] reported that all subscales of the SF36 form showed significant improvement in response to the ILEX resistance training intervention. In addition they asked participants to rate their outcome as either ‘better,’ ‘same’ or ‘worse’ which between the two centres ranged respectively from ~74% to ~82%, ~12% to ~ 24% and ~1% to 5%. Willemink et al. [60] measured GPO at 12 and 24 weeks of their ILEX resistance training intervention as 1 = ‘completely recovered,’ 2 = ‘much improved,’ 3 = ‘slightly improved,’ 4 = ‘no change,’ 5 = ‘slightly worsened,’ 6 = ‘much worsened,’ and 7 = ‘worse than ever.’ The results respectively were rated 1 or 2 = 43.8%, 3 to 5 = 56.3%, and 5 to 7 = 0% at 12 weeks, and 1 or 2 = 50.0%, 3 to 5 = 37.6%, and 5 to 7 = 12.5% at 24 weeks.

Recently, international consensus has been offered on what is referred to as the ‘Minimal Clinically Important Change’ (MCIC) for changes in measures of perceived pain and disability [64]. The MCIC refers to the minimal change required in an outcome variable for it to have any meaningful impact upon a participant’s perception of the overall outcome from an intervention. Thus it is usually considered with reference to the mean change found in a group for such a variable that has also reported a minimal positive perception of outcome in some form of GPO [65,66]. Ostelo et al. [64] have suggested MCICs of 15mm for VAS, 10pts for ODI, 5pts for RMDQ or at least a 30% improvement from baseline. Considering these MCICs the studies reported here examining ILEX resistance training interventions consistently achieve these outcomes for VAS [42-48,50,51], ODI [46-48,50,51,58], and RMDQ [59-62], with few exceptions [42,49,52,56] where participants in these studies had very low baseline ODI and VAS scores which may account for the lack of MCIC. Al-Obaidi et al. [59] have reported that pre-intervention characteristics including fear avoidance beliefs and initial pain intensity may affect whether MCICs are met through ILEX resistance training, suggesting higher scores in both these characteristics predict failure to meet MCIC. However, the intention to treat analysis used in this study included 6 participants who did not complete the intervention as not achieving the MCIC, though reasons for not completing the intervention are not reported.

A number of studies have also examined whether improvements in pain and disability produced through ILEX resistance training interventions are long-lasting. Nelson et al. [54] followed up participants 1 year after and reported that 94% of participants who had previously reported a GPO of either 'good' or 'excellent' had maintained these outcomes. This occurred despite low adherence to a prescribed program of home-based exercises during follow up (53%). Leggett et al. [55] conducted 1 year follow ups in both centres used in their study reporting maintenance of positives outcomes on the SF36 from discharge to 1 year at both centres. Choi et al. [47], however, in post lumbar discectomy participants showed that at 1 year follow up VAS was similar for both the group training using ILEX resistance training and also the non-training control group; however, the ILEX resistance training group produced a significantly greater reduction in pain post intervention thus benefiting from a longer period of time with minimal pain after surgery. Helmhout et al. [61,62] and Harts et al. [63] in randomised trials conducted 9 month and 16 week follow ups post 8 to 10 weeks of ILEX resistance training 1 to 2x/week with samples of 81 and 65 participants respectively. They also reported maintenance of outcomes for pain and disability over the follow-up however a number of participants (84%) elected to continue with the ILEX resistance training intervention over this period.

Collectively a range of studies, including both prospective single arm trials and randomised controlled trials, suggest ILEX resistance training is effective in producing reductions in pain and disability that are significant, clinically meaningful and may also be long-lasting.. However, these studies have utilised varied applications of this exercise approach and thus examination of control of the specific resistance training variables (i.e. the dose of exercise [67,68]) is key to providing recommendations on the best means of employing ILEX resistance training in practice. Some have suggested following the American College of Sports Medicine's [69,70] recommendations for resistance training prescription [31]. However these have received criticism and alternative evidence based recommendations of resistance training to improve strength, endurance and hypertrophy have been recently reviewed and suggested [71-73]. Further, most studies examining recommendations for application of ILEX resistance training have been conducted in asymptomatic populations [17,74-76]. Though these support recent recommendations for an approach involving a single set of repetitions performed to momentary muscular failure using a load that permits ~8-12 repetitions before reaching failure, performed in a slow and controlled manner, at a frequency of around once per week to improve strength, endurance and hypertrophy [71-73], whether training in this manner using ILEX resistance training is most efficacious for improving pain, disability or other outcomes in symptomatic participants is a different question. As such the next section will report research that has looked to clarify the manipulation of specific resistance training variables (intensity of effort, load/repetition range, repetition duration, volume, frequency and range of motion) using ILEX resistance training so as to offer recommendations for its application in symptomatic populations.

Manipulation of Resistance Training Variables for use of ILEX Resistance Training

Two studies have examined the effect of altering 'intensity' of lumbar extension resistance training using ILEX resistance training [61,63] comparing 'high intensity training' (HIT) with 'low intensity training' (LIT) [61] and also with a waiting list control group [63] reporting no difference between groups for improvement in disability (RDMQ), or overall outcome (SF36 and GPOs) for HIT and LIT [61], and or between HIT, LIT and a waiting list control [63]. However, unfortunately these studies were not appropriately designed and controlled to examine the effects of 'intensity' and have been recently commented upon [77]. In addition more appropriate definition and use of the term 'intensity' in resistance exercise has been suggested [72,73,77,78]. Recent proposals [77] define that *'intensity refers to the degree or magnitude of a measurable characteristic or variable'* and thus cannot specifically be considered to refer to a particular variable (e.g. *load* or *effort* as is most common). Comparison of load requires control of effort by having participants train to momentary muscular failure (MMF [77]). Training for the HIT group in the first study [61] used 35% of their max ILEX strength, whereas the LIT group used 20%. In the second study [63], load was increased for the HIT group to 50% of their maximal lumbar extension strength whilst keeping the LIT group's training the same as previously. In neither study did the participants train to MMF.

Although intensity of *load* differed, it is impossible to know the degree to which *effort* also differed between HIT and LIT [61,63] . Effort increases with increased load assuming all other variables are constant, yet the loads used and the degree of difference between HIT and LIT was small (HIT used 35%/50% of max strength, LIT used 20% of max strength). In fact the LIT group may have trained at a relative load similar to the HIT group as the author's note even the lowest possible load the ILEX device could not permit 20% in some participants [61]. Considering typical repetitions ranges possible at different relative loads [79,80], and the repetitions ranges used within these studies, both groups likely trained at similarly low effort. Thus lack of significant differences between groups is unsurprising. Further, HIT and LIT were presented to the participants as *"potentially equally effective for the lower back while targeting different aspects: strength in the HIT group versus mobility in the LIT group"* (pp 540 [61]) thus it is unsurprising that the HIT group made greater improvements in strength whereas the LIT group made greater improvements in TSK reflecting fear of movement. Despite the relatively low effort approach used by both HIT and LIT, the HIT group likely trained at a marginally higher effort and most outcomes showed a trend towards greater improvement in this group [61,63]. That intensity of effort may be an important factor to consider in determining the effectiveness of ILEX resistance training has recently been noted [81]. Other studies already mentioned in which participants have completed repetitions to MMF have shown significant improvements in all outcomes compared to non-training control groups [46,48,50,53,54] in contrast to the results of the waiting list control group comparison by Harts et al. [63]. Although increased load increases effort when repetitions performed are matched, no studies have directly examined the effect of different loads independently on clinical outcomes in CLBP whilst controlling for other variables. Neither have any studies directly compared differing repetition durations nor different set volumes in symptomatic participants.

Frequency of training has varied in studies of ILEX resistance training utilising either a 2x/week training frequency or a mixed training frequency of 2x/week for the first 2 to 4 weeks followed by training 1x/week for the remainder of the intervention. Kim et al. [52] examined 40 participants recovering from lumbar discectomy training 2x/week, 1x/week, 1x/2weeks, or a non-training control. After surgery participants completed 12 weeks of training using ILEX resistance training at a frequency of 2x/week. Participants were then tested for lumbar extension strength, ODI and VAS before then being randomised into a group training 2x/week, 1x/week, 1x/2weeks, or a non-training control. The group training 1x/2weeks did not significantly improve either ODI or VAS. ODI improved significantly in both the 1x/week and the 2x/week groups whereas VAS only significantly improved in the 2 x/week groups. However, both VAS and ODI were very low when first measured after surgery and the initial 12 week training (0.9cm to 1.0cm and 10.4pts to 10.8pts respectively). Before surgery participants' VAS scores ranged from 7.7cm to 8.7cm and ODI from 83.8pts to 85.2pts indicating improvement from before surgery to the first measurement of these variables. However, during the time between these two measurements both surgery *and* 12 weeks of initial ILEX resistance training was performed it is unclear as to what degree either exerted these improvements. Bruce-Low et al. [50] examined the effect of either 1x/week or 2x/week ILEX resistance training over a 12 week intervention upon VAS and ODI. They reported no significant differences between improvements in VAS or ODI for either 1x/week or 2x/week training.

Steele et al. [46] recently examined the effects of manipulation of range of motion (ROM) during ILEX resistance training comparing full ROM to limited ROM (performed using only the mid 50% of the participants full ROM) training over 12 weeks. They reported no significant differences between improvements in lumbar extension strength across the full ROM in agreement with previous literature in asymptomatic participants [82]. In addition there were no significant differences in improvements for VAS and ODI when training either using full or limited ROM ILEX resistance training.

Despite the lack of controlled research examining clinical outcomes in response to different load, set volumes and repetition durations, collectively research suggests that low frequency (1x/week) yet high effort (to momentary muscular failure) ILEX resistance training performed through either a full or limited ROM elicits can be recommended for best improvements in pain and disability. Though research indicates positive outcomes from ILEX resistance training and allows some specification of recommendations for achieving such outcomes, the question of its efficacy in comparison to other specific exercise approaches and alongside other co-interventions remains. The next section will report studies of different specific exercise approaches compared with ILEX resistance training in addition to its efficacy as a single intervention or part of multiple interventions.

Studies of ILEX Resistance Training and other Specific Exercise Approaches.

Randomised controlled trials using ILEX resistance training with symptomatic participants appear to have only been conducted in comparison to floor/stability ball exercise approaches, and other TEX resistance machines. Udermann et al. [83] reported no differences between 4 weeks of McKenzie exercise with and without ILEX resistance training 1x/week on 6 significantly improved subscales of the SF36 including pain in a sample of 18 participants. Helmhout et al. [62] also reported no differences between a regular physiotherapy group and a group performing isolated lumbar extension resistance training using ILEX resistance training over 10 weeks and over 6 and 12 month follow-ups. The physiotherapy group performed a variety of treatments with the physiotherapist including 65% of activities as exercise (i.e. trunk and leg strengthening - though physiotherapists were instructed to not use the specific lumbar extension device - core stability exercises, stretching and specific McKenzie exercise), 25% constituted aerobic activity, 10% instruction and advice, and less than 1% as passive modalities. However, one participant included in the physiotherapy group undertook ILEX resistance training and 2 of the 6 centres used during the study reported utilising the ILEX resistance training device despite being instructed not to for the physiotherapy group. Participants in the physiotherapy group that also received ILEX resistance training were included in analysis despite the co-intervention whereas two participants from the group exclusively training on the ILEX resistance training machine who also accidently received a manual therapy co-intervention were excluded from analysis. The selectivity of participant inclusion for analysis is unclear as the authors reported following ‘intention to treat’ principles.

Smith et al. [48] conducted a randomised controlled trial involving two groups performing a 12 week training intervention 1x/week and a non-training control group. The two training groups performed exercise using an ILEX resistance training device, however, one group trained with the restraints tightened as per the manufacturer’s recommendations (thus providing ILEX) and the other group trained without the use of the restraints. The results showed that only the group training with use of the restraints (i.e. ILEX) improved in any of the outcomes measured which included lumbar extension strength, VAS and ODI.

Many of the studies that have utilised ILEX resistance training and reported that its effectiveness have used it alongside numerous co-interventions thus rendering it impossible to definitively conclude that the effective part of the intervention is indeed the inclusion of ILEX resistance training. For example, many studies have included co-interventions including; other forms of resistance training exercise (including machines and free weights), aerobic exercise using ergometers (i.e. cycle, treadmill etc.), and also behavioural and lifting education [42,47,49,51,54-56,83,84]. Other studies however have examined the use of ILEX resistance training as a single intervention [43-46,48,50,52,53,58-63,83,84]. The results of both studies of ILEX resistance training as a single or co-intervention suggest similar efficacy between both approaches. Interventions using ILEX resistance training alongside co-interventions have shown improvements of approximately ~30% to ~50% gains in lumbar extension strength, ~26% to ~69% improvement in pain using either SF36 or VAS (~15mm to ~55mm), and ~17% to ~30% improvement in ODI score (2.21pts to 5.33pts), compared with studies of ILEX resistance training as a single intervention reporting ~20% to ~55% gains in lumbar extension strength, ~55% improvement in pain measured through VAS (~16mm to ~21mm), ~30% to ~50% improvement in ODI score (~10pts to ~14pts), and ~16% improvement measured using the RMDQ. A randomised controlled trial by Vincent et al. [84] has recently compared the use of ILEX resistance training as a single intervention with ILEX resistance training as part of a full body machine based resistance training intervention in addition to a control group undergoing standard care (including bodyweight resistance exercises, dietary information and information about back pain) in 49 obese participants with CLBP. They reported that improvements in ODI, RMDQ and pain catastrophising were significantly greater in the full body training group compared with the single ILEX resistance training group. However, they only report group x time effects and do not report *p* values for pairwise comparisons were the changes reported for ODI qualitatively appear greater for the full body group (-11.4pts) compared with ILEX resistance training (-6pts) and controls (-1.5pts). Though results for the RMDQ and for lumbar extension strength respectively suggested greater improvements both the full body group (-4.7pts and 40Nm) and control group (-2.1pts and 35Nm) compared to the ILEX resistance training group (-1.1pts and 23Nm) suggesting the manipulation of resistance training variables in the ILEX resistance training intervention (e.g. they did not train to MMF) may have been insufficient to address lumbar extensor deconditioning in these participants.

DISCUSSION Three areas were considered for the purposes of this review; 1) ILEX resistance training's efficacy upon perceived pain, disability and GPOs including the clinical meaningfulness of these outcomes in CLBP, 2) the manipulation of ILEX resistance training variables for best outcome to provide recommendations for clinical prescription, 3) and the comparatison of ILEX resistance training and other specific exercise approaches, including use of ILEX resistance training as part of a multiple or single intervention approach. The studies reviewed under these areas demonstrate that interventions using ILEX resistance training consistently produce significant improvements in both pain and disability which consistently meet MCICs. For practitioners considering the implementation of ILEX resistance training when working with persons suffering from CLBP evidence suggests that a low frequency (1x/week) yet high intensity of effort (to momentary muscular failure) approach using either full or limited range of motion ILEX resistance training is most effective. There is a lack of studies examining with appropriate control the impact of manipulating different load, set volumes and repetition duration thus prudence suggests following recent evidence based recommendations regarding these variables for resistance training may be sensible [71-73]. Further, comparison with other specific exercise approaches has not been tested as rigorously as is desired in some studies due to short duration of intervention [83] in addition to comparisons being confounded by both groups using ILEX resistance training [62]. However, one study suggests ILEX resistance training may be better than other specific exercise approaches [48] and studies suggest similar efficacy whether used as a single intervention or alongside co-interventions.

The nature of exercise performed using ILEX resistance training allows for an accurate quantification of the dose provided and specific application of this dose to an isolated area. In addition to this, the testing features of some ILEX resistance training devices allow accurate quantification of treatment progress. Finally, ILEX resistance training is a time efficient strategy for tackling CLBP [88]. ILEX resistance training sessions require at least ~50%

less time compared to regular physical therapy [62]. A recent analysis suggests that greater benefit may occur with a greater frequency of exercise sessions (an additional eight sessions required to improve VAS scores by 1mm compared to controls [36]). ILEX resistance training specifically however is apparently very effective with only a single weekly session with no further benefit from additional sessions [50]. It seems clear also that ILEX resistance training is just as effective as an individual treatment approach [43-46,48,50,52,53,58-63,83,84] and that the benefits can occur from as little as one session per week taking approximately 10-15 minutes with only 1-2 minutes of that comprising exercise. As one of the biggest economic losses through CLBP occurs due to work hours lost both through treatment and absenteeism, a workplace strengthening program [42,85-87] using ILEX resistance training could be an effective occupational approach.

Mooney et al. [85] demonstrated that the use of a rehabilitation protocol using ILEX resistance training in a strip mining facility with higher than average injury rates resulted in significantly reduced injuries and a reduction of workers compensation costs from $14,430 per month to $380 per month. In addition Matheson and Mooney [86] report the results of a study [87] conducted within the airline industry utilising an ILEX resistance training program with 622 workers and 2937 control workers. Back injuries in the exercise group were 5.7 per year compared to 179 per year in the control group. A difference in costs was also noted, with cost of back injuries at $206 in the exercise group and $4,883 in the control group. Initial return to work also is considerably higher in post lumbar discectomy patients undergoing ILEX resistance training compared to home-exercise based controls (87% ILEX resistance training compared to 25% controls [47]). In those off work due to CLBP related complaints (~73 days off work) initial return to work following ILEX resistance training is around 72% [54]. Nelson et al. [88] also showed that the use of a rehabilitation program using ILEX resistance training for those with LBP who had originally been referred for spinal surgery resulted in only 7% of the participants requiring the expensive procedure. On average the cost of ILEX resistance training program in this study was $1950 compared to average total surgical costs ranging from $60,304 - $168,732. Large scale studies [54,55] with one year follow ups have also shown that direct health care costs may be reduced as those rehabilitated using ILEX resistance training were significantly less likely to re-utilise the general health care system. It should be noted that health care re-use due to ineffective treatment is one of the most significant contributors to total costs of LBP [19]. Thus it seems that in terms of costs ILEX resistance training perhaps offers an effective solution.

The use of progressive specific resistance exercise in treating CLBP appears relatively uncommon at present, and the use of ILEX resistance training specifically even less so. For example, in the UK, according to one ILEX device company website (MedXonline.com), there are only 5 facilities with access to their ILEX device (though the authors of this manuscript are aware of two others). Compared with the availability of their device in the United States there is quite a difference. Within 75 miles of Los Angeles alone there are at least 49 facilities each providing access to an ILEX device. If this is representative of other ILEX devices then on the whole availability seems limited in comparison with other specific exercise approaches. It seems peculiar that there is relatively little access to the equipment despite evidence supporting its use, and the current burden of CLBP. Some concerns may be with the initial cost of purchasing such equipment [20] and depreciation costs of materials [89]. However, when weighed against the costs to taxpayers and employers incurred by LBP, the cost of ILEX device purchase is paltry [20]. The use of ILEX resistance training can further help to alleviate high costs involved with surgery [88], the direct cost of health care re-utilisation [54,55] and the indirect costs involved with loss of work hours and insurance claims [85,87]. In addition there are a range of ILEX devices available commercially which range in price (e.g. Lumbar Extension Machine, MedX, Ocala, Florida; BackUp Dynamometer, Priority One Equipment, Grand Junction, Colorado; Lower Back Revival System, OriGENE Concepts BV, Delft, the Netherlands etc.). Some offer sophisticated testing options whereas others are purely for exercise use. Although sophisticated testing might be desirable in research it may be less of a concern to clinicians and so more ‘low tech’ options might be considered. The reliability of ILEX resistance training use in treatment between separate facilities has also been shown [55] and this would suggest that if more health care facilities were to obtain ILEX devices the results gained from treatment would be consistent across facilities. The costs of ILEX resistance training should be weighed against the benefits (including reduction of treatment time through its minimal approach) when making decisions in this regard [89].

Despite the current body of research in this area there is scope for further research regarding ILEX to be conducted. There is a lack of rigorous research examining ILEX resistance exercise in comparison with other specific exercise approaches. Also, considering this, the extent of potential placebo effects, though difficult to examine in exercise based studies [90], is an area regarding ILEX resistance training also requiring examination as it is noted that engagement in any type of exercise might offer some benefit through such means [91,92]. CLBP is being considered more commonly as a multifactorial disorder with an array of symptoms and associations [15,16]. The use of ILEX resistance training however has yet to be considered in the wider scope of CLBP’s multifactorial nature. Some suggest it may offer a range of treatment effects [89]. Yet it is unknown whether it may also confer as yet unseen benefits to other aspects of physical function and symptoms associated with CLBP as might be deduced from speculations regarding the role of lumbar extensor deconditioning in low back pain and injury [17-21]. Indeed, although a proposed mechanism of action is the specific strengthening of the lumbar extensor musculature that this type of treatment offers and there is some evidence to support a link between clinical improvements and strength improvements [46,54,81], it is necessary to further examine the 'black box' of treatment mechanisms as this has recently been questioned [60,91,92]. Lastly, as some have complained of the costs involved with specialised equipment such as ILEX devices, future research should look to the possibility of the effects of other specific exercise (i.e. those described by Mayer et al. [29]) as a kind of 'maintenance' program that could be performed after an initial specific exercise program using ILEX resistance training so as to reduce participants reliance upon specialised equipment, supervision and locations.

CONCLUSION

In conclusion, the studies considered in this review suggest that an ILEX resistance training intervention of low frequency (1x/week) yet high intensity of effort (to momentary muscular failure) approach using either full or limited range of motion, either as a single approach alongside co-interventions, is effective in producing significant and clinically meaningful improvements in pain and disability for those with CLBP. However, due to lack of research, it is less clear as to whether these improvements are in fact greater than might be achieved through other specific exercises.

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Figures

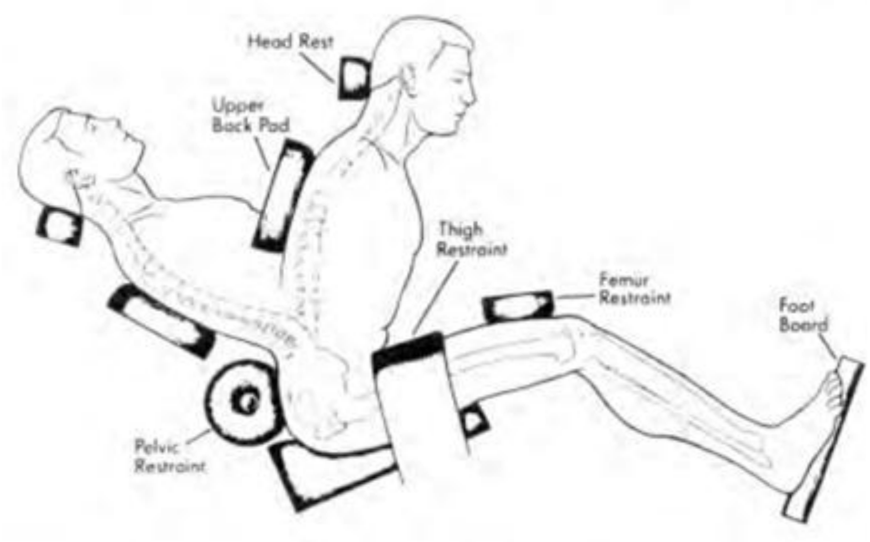

Figure 1. Example of a restraint system used to allowed isolated lumbar extension (ILEX) resistance training to be performed (Reprinted with permission from MedX Corporation)

Table 1. Summary of studies examining ILEX in CLBP upon pain, disability and GPOs

Study	Participants	Method	Outcome	Achieved MCICs [104] for VAS or ODI?	Follow up?
Mooney et al. [42]	29 females, 26 males with CLBP	All participants underwent an 8 week intervention 2x/week using ILEX resistance training, other resistance training exercises and bike, stair or treadmill exercise. Load, whether exercise was performed to MMF, sets, repetitions, repetition duration, and ROM for ILEX was not reported Pre and post VAS and ODI were completed.	Significant improvement in both VAS (12.3mm – 18.3mm; *p* = 0.0001) and ODI (2.12pts – 2.29pts; *p* = 0.001).	VAS achieved MCIC. ODI failed to achieve MCIC.	N/A
Park et al. [43]	6 males and 22 females (age ~42 years) with CLBP	Participants underwent an 8 week intervention 2x/week using ILEX resistance training Load was estimated at ~50-70% of max isometric torque and 10 repetitions performed. Whether exercise was performed to MMF, sets, ROM and repetition duration for ILEX was not reported. VAS and daily activity level were completed pre and post.	Significant improvement in VAS (30mm; *p* < 0.01) and daily activity level (*p* < 0.05).	VAS achieved MCIC	N/A
Lee et al., [44]	29 participants with CLBP	Participants underwent an 8 week intervention 2x/week using ILEX resistance training VAS was completed pre and post.	Significant improvement in VAS (26mm; *p* < 0.05)	VAS achieved MCIC	N/A
Holmes et al. [45]	18 females (Age 68.2±7.5 years, stature 162.8±7.5 cm, body mass 63.2±10.3 kg) with CLBP	Participants underwent intervention 2x/week for the first 4 weeks reducing to 1x/week if participants did not increase pain during sessions using ILEX resistance training A single set of ILEX a load permitting 20 repetitions through their full ROM before MMF using a slow controlled manner taking at least 3-4 seconds for each repetition. Load was progressed	Participants significantly improved VAS (~3.2 pts; *p* < 0.05)	VAS achieved MCIC	N/A

		once the participant could complete more than 20 repetitions. Load was not reported. VAS (10 pts scale) was completed pre and post			
Steele et al. [46]	14 males and 10 females (age ~41-46 years, stature 173-180 cm, body mass 75-85 kg) with CLBP	10 participants underwent a 12 week intervention 1x/week using ILEX resistance training with a full ROM 7 participants underwent a 12 week intervention 1x/week using ILEX resistance training with a limited ROM (mid 50% of their full ROM) Both groups performed a single set of ILEX using 80% of their max isometric torque permitting 8-12 repetitions (70-105 seconds) before MMF using a slow controlled manner taking 2 seconds for the concentric phase, holding for 1 second in extension, and 4 seconds for the eccentric phase. Load was progressed by 5% once the participant could complete more than 12 repetitions. 7 participants acted as non-training controls VAS and ODI were completed pre and post	Both ILEX groups significantly improved in VAS (~16-30mm) and ODI (~12-18pts) compared to the control group ($p < 0.05$) with no significant difference between ILEX groups.	VAS and ODI achieved MCIC	N/A
Choi et al. [47]	38 males and 37 females (age ~42-51 years, stature ~165 cm, body mass ~63-67 kg) undergoing first time lumbar discectomy for disc herniation not responding to conservative treatment	35 participants underwent a 12 week intervention 6 weeks post-surgery using ILEX resistance training, other resistance training exercises and aerobic exercise. Load, whether exercise was performed to MMF, sets, repetitions, repetition duration, and ROM for ILEX was not reported	ILEX group improved significantly more compared to the control group in VAS at the end of the 12 week intervention (ILEX group 57mm, Control group 38mm). No significant difference between groups for change in ODI	VAS and ODI achieved MCIC	At 4 months post-surgery 87% of the ILEX group had returned to work compared to 24% of the controls At 6 months post-surgery ~92% of both groups had returned to work At 1 year follow up VAS was similar between groups

		40 participants constituted a control group completing 12 weeks of home-based lumbar conditioning exercises No details of home-based exercises were reported VAS and ODI were completed pre and post and during follow-up. Return to work 4 months after surgery was also reported.			
Smith et al. [48]	42 participants (age 42.93±10.80 years) with CLBP	15 participants underwent a 12 week intervention 1x/week using an ILEX resistance training with the restraints fastened (STAB). 15 participants underwent a 12 week intervention 1x/week using an ILEX resistance training without the restraints fastened (NO-STAB). Both groups performed a single set of ILEX using a load that permitted 8-12 repetitions before MMF through a full ROM using a slow controlled manner taking 2 seconds for the concentric phase and 4 seconds for the eccentric phase. Load was progressed by 5% once the participant could complete more than 12 repetitions. 12 participants acted as non-training controls VAS and ODI were completed pre and post	STAB significantly improvement in both VAS (~17mm; *p* < 0.01) and ODI (~12pts; *p* < 0.01). No change was observed for NO-STAB or control groups for either VAS or ODI.	VAS and ODI achieved MCICs in the STAB group	N/A
Ju et al. [49]	14 participants (age ~45 years, stature ~162 cm, body mass ~63 kg) undergoing lumbar disc herniation surgery	7 participants underwent a 12 week intervention 3x/week post-surgery using ILEX resistance training and other resistance training exercises ILEX was performed using 40-50% of max isometric torque for	ILEX group improved significantly in all VAS measures at the end of the 12 week intervention (back pain ~7.6 mm, night pain 9.3 mm, exercise pain 27.5 mm, handicap 29.9 mm; all *p* < 0.05).	VAS for back pain did not meet MCIC	N/A

		18-20 repetitions. Load was progressed based upon results of retesting every 4 weeks. Sets, repetition duration, and ROM for ILEX was not reported. 7 participants constituted a control group completing rest and utilising conservative treatments. VAS for back pain. Night pain, exercise pain and handicap were completed pre and post.	The control group made no significant improvement.		
Bruce-Low et al. [50]	42 males and 30 females (age 45.5±14.1 years) with CLBP	31 participants underwent a 12 week intervention 1x/week using ILEX resistance training 20 participants underwent a 12 week intervention 2x/week using ILEX resistance training The 1x/week group performed a single set of ILEX using 80% of their max isometric torque permitting 8-12 repetitions (70-105 seconds) before MMF through a full ROM using a slow controlled manner taking 2 seconds for the concentric phase, holding for 1 second in extension and 4 seconds for the eccentric phase. Load was progressed by 5% once the participant could complete more than 12 repetitions. The 2x/week group perfmored the same session as above in addition to performing a single set of ILEX using 50% of their max isometric torque permitting 15-20 repetitions (105-140 seconds) before MMF through a full ROM using a slow controlled manner taking 2 seconds for the concentric phase, holding for 1 second in extension and 4 seconds for the eccentric phase. Load was progressed by 5% once the	Both ILEX groups significantly improved in VAS (~16-21mm) and ODI (~12-15pts) compared to the control group ($p < 0.05$) with no significant difference between ILEX groups.	VAS and ODI achieved MCIC	N/A

		participant could complete more than 20 repetitions. 21 participants acted as non-training controls VAS and ODI were completed pre and post			
Stephan et al. [51]	74 participants (55% females, age ~44 years) with CLBP	58 Participants underwent an intervention lasting and average ~24.5 weeks of average ~1.6x/week using ILEX resistance training and other resistance training exercises. ILEX and other exercises were performed for a single set using 60% of their 1 repetition maximum permitting 6-9 repetitions stopping prior to MMF for sessions 1-20 and achieving MMF from session 21 onwards, using a slow controlled manner taking 4 seconds for the concentric phase, holding for 2 second in extension, and 4 seconds for the eccentric phase through full pain free ROM. Load was progressed was not reported. 18 participants acted as non-training waiting list controls VAS, pain severity and effects of pain were measured using the MOS in addition to ODI were completed at 3 and 6 months.	Significant reductions in VAS, pain severity, effects of pain and ODI were seen at 3 and 6 months (all $p < 0.001$). The control group significant reduced ODI at 3 months ($p < 0.05$) and pain severity at 6 months ($p < 0.05$) but did not significantly change in any other measure.	Both VAS and ODI met MCIC	N/A
Kim et al., [52]	40 male patients undergoing surgery for lumbar discectomy (Age ~40 years, stature ~173 cm, body mass ~75kg)	All patients underwent lumbar discectomy followed by 6 weeks of rest. After lumbar discectomy and 6 week rest all participants underwent a 12 week intervention 2x/week using ILEX resistance training	Group 3 did not improve in either VAS or ODI Group 1 and 2 both significantly improved in ODI (0.8 to 1.4 pts; $p < 0.05$) Only Group 1 significantly improved VAS (0.5 cm; $p < 0.05$)	VAS and ODI did not meet MCICs	N/A

		After completion of the initial 12 week intervention: 10 participants underwent a 12 week intervention 2x/week using ILEX resistance training (Group 1) 10 participants underwent a 12 week intervention 1x/week using ILEX resistance training (Group 2) 10 participants underwent a 12 week intervention 1x/2weeks using ILEX resistance training (Group 3) Each group performed 2 sets of ILEX permitting 15-20 repetitions taking 3 seconds for the concentric phase, and 3 seconds for the eccentric phase. Load, ROM and progression for ILEX was not reported 10 participants acted as non-training controls VAS (for LBP and leg pain) and ODI were completed post-surgery and initial 12 week intervention and again post the further 12 week intervention			
Risch et al. [53]	34 males and 20 females (age ~45 years range 22-70) with CLBP	31 participants underwent a 10 week intervention using ILEX resistance training 2/week for the first 4 weeks, 1x/week for the last 6 weeks. A single set of ILEX was performed using 50% of their max isometric torque performed to MMF through a full ROM. Load was progressed by 5 ft.lb once the participant could complete more than 12 repetitions. Repetition	In the intervention group there was a significant improvement in pain subscale of West Haven Yale Multidimensional Pain Inventory (~0.5; $p < 0.002$). No significant changes occurred for the control group.	N/A	N/A

		duration for ILEX was not reported 23 participants acted as a waiting list control group. Both completed pre and post West Haven Yale Multidimensional Pain Inventory.			
Nelson et al. [54]	484 males (mean age 38.7 years) and 411 females (mean age 37.1 years) with CLBP were initially recruited	627 participants completed an average of 18 sessions 2x/week using ILEX resistance training, other resistance training exercises and aerobic exercise. ILEX was performed alternating between sessions to MMF and sessions not to MMF. Load, sets, repetitions, repetition duration, and ROM for ILEX was not reported 107 participants acted as non-training controls. All participants underwent educational sessions and were given a home-based exercise program to utilise during follow-up Pre and post pain was measured using a 5 item scale as well as GPOs. Return to work initially and at 1 year follow-up was also reported.	In the intervention group 64% and 62% reported substantial decrease in pain, 14% and 17% reported a decrease in pain, 6% and 6% reported a slight decrease in pain, 12% and 13% reported no change in pain, and only 3% and 2% reported a worsening of their pain. The intervention group reported GPO's of 46%, 30%, 14% and 8% for 'excellent,' 'good,' 'fair' or 'poor' respectively. Of 139 participants off work due to CLBP (~73 days) 72% returned to work at completion of the ILEX intervention	N/A	At 1 year follow up 94% of participants with good or excellent results maintained improvement, 6% did not change or worsened. Of participants with fair or poor results 25% improved, 75% did not change or worsened Return to work at 1 year follow-up was at 77%
Leggett et al. [55]	192 males (age ~39-49 years) and 220 females (age ~39-51 years) with CLBP	Participants underwent an 8 week intervention 2x/week using ILEX resistance training, other resistance training exercises, aerobic exercise and McKenzie therapy. ILEX was performed using 50% of their max isometric torque performed to MMF through a full ROM. Load was progressed by 2-	Significant improvement in all subscales of SF36 ($p < 0.0001$). ~74% to ~82%, ~12% to ~ 24% and ~1% to 5% rated their outcome as either 'better,' 'same' or 'worse' between the two centres used	N/A	At 1 year follow up maintenance of outcomes was apparent

		5% once the participant could complete more than 15 repetitions. Sets and repetition duration for ILEX was not reported SF36 and GPOs were completed pre and post.			
Costa [56]	4 males and 5 females (age ~63 years) with CLBP	Participants underwent an 8 week intervention 2x/week using ILEX resistance training and other resistance training exercises. A single set of ILEX was performed for 8-12. Load was progressed based upon participant’s perception as exercise became easier. Load, repetition duration, and ROM for ILEX was not reported McGill Pain Questionnaire and ODI were completed pre and post.	Significant improvement in ODI (5.33pts; $p = 0.033$) but not in McGill Pain Questionnaire (3.22pts; $p = 0.159$)	ODI failed to achieve MCIC.	N/A
Carlson & MacKay, [58]	28 males (age ~47 range 25-80 years) and 27 females (age ~46.9 range 26-73 years) with CLBP	Participants underwent a 6 week intervention 2x/week using ILEX resistance training. ILEX was performed using a load that permitted 6-9 repetitions before MMF through a full ROM using a slow controlled manner taking 4 seconds for the concentric phase, holding for 2 seconds in extension and 4 seconds for the eccentric phase. Load was progressed by 5% once the participant could complete more than 12 repetitions. Load, sets, and ROM for ILEX was not reported ODI was completed pre and post.	Significant improvement in ODI (9-10.8pts; $p < 0.05$)	ODI achieved MCIC	N/A
Al-Obaidi et al. [59]	42 participants were initially recruited, 22 males (age 45±6.2 years) and 20 females (age 39.25±5.8 years) with CLBP	36 participants underwent a 10 week intervention 1x/week using ILEX resistance training. A single set of ILEX was performed using a load permitting	RMDQ scores significantly improved (~4 pts, ~16%; $p < 0.001$).	RMDQ achieved MCIC Participants were however dichotomised individually as to whether MCIC was met and fear avoidance beliefs and	N/A

		6-12 repetitions before MMF using a slow controlled manner throughout the full ROM. Load was progressed by 5% once the participant could complete more than 12 repetitions. Load and repetition duration was not reported. RMDQ was completed pre and post		baseline pain shown to be higher in those failing to achieve MCIC	
Willemink et al. [60]	20 participants (Age 46.2±9.7 years) with CLBP	Participants underwent an ILEX resistance training intervention lasting ~24 weeks including 10 session during the first 12 weeks and sessions at participants convenience for the second 12 weeks 4 sets of ILEX for 10 repetitions were performed at a load determined by the physiotherapist through a full ROM using a slow controlled manner taking 2 seconds for the concentric phase, and 3 seconds for the eccentric phase. Load was progressed once the participant could complete 4 sets comfortably RMDQ, GPO and patient functional scale (PFS) were completed pre, at 12 weeks post and 24 weeks post.	RMDQ significantly improved at both week 12 and 24 (~3 pts, ~13%; *p* = 0.024) PFS significantly improved at both week 12 and 24 (~70 pts; *p* < 0.001) GPO showed complete recovery or significant improvement in 43.8% and 50.0% at weeks 12 and 24 respectively	RMDQ achieved MCIC	N/A
Helmhout et al. [61]	81 male working army participants (age ~40 years) with CLBP	Participants underwent a 10 week intervention 2x/week for weeks 1-2 and 1x/week for weeks 3-12 using ILEX resistance training either as ‘High Intensity’ (HIT) or ‘Low Intensity’ (LIT). For HIT load was 35% of max isometric torque and 15-20 repetitions performed during weeks 1-2 and 10-15 repetitions performance weeks 3-12. Load was progressed by 2.5kg once the participant could complete more	No significant differences between groups were found for self-assessed improvement, RMDQ, ODI or SF36. TSK was significantly greater in LIT midway through the intervention (~0.4pts; *p* = 0.03). Lumbar extension strength was significantly greater for HIT at all time points (~31-58 Nm; *p* < 0.001).	ODI achieved MCIC for both groups	No significant differences between groups were found for self-assessed improvement, RMDQ, ODI or SF36 at 6 or 9 months follow-up. TSK was significantly greater in LIT at 9 months follow-up (~3.4pts; *p* = 0.03). Lumbar extension strength was significantly greater

		than 20 repetitions. Whether exercise was performed to MMF, sets, repetition duration and ROM for ILEX was not reported. For LIT load was 20% of max isometric torque and 15 or 20 repetitions performed during weeks 1-2 and weeks 3-4 after each test. Whether exercise was performed to MMF, sets, repetition duration and ROM for ILEX was not reported. RMDQ, ODI, TSK and SF36 were completed pre and post. Follow-up was conducted at 6 and 9 months.			for HIT at 6 and 9 months follow-up (~24-29 Nm; $p < 0.05$).
Helmhout et al. [62]	107 male working army participants (age ~35-37 years, stature ~183 cm, body mass ~85kg) with sub-acute LBP or CLBP	61 participants underwent a 10 week intervention 2x/week using ILEX resistance training. Load was estimated at ~50-70% of max isometric torque and 15-20 repetitions performed in a slow controlled manner taking 2 seconds for the concentric phase and 4 seconds for the eccentric phase. Load was progressed by 2.5kg once the participant could complete more than 20 repetitions. Whether exercise was performed to MMF, sets, and ROM for ILEX was not reported 46 participants underwent a 10 week intervention using Regular Physiotherapy. Regular Physiotherapy included including 65% of activities as exercise (i.e. trunk and leg strengthening - though physiotherapists were instructed to not use the specific lumbar extension device, core stability exercises, stretching and specific McKenzie exercise), 25%	No significant between groups differences for improvements in RMDQ (~4-5pts), PSFS (~60mm) at any time.	RMDQ achieved MCIC for both groups	Follow up conducted at 36 and 62 weeks showed that improvements were maintained for both groups with no between group differences

		constituted aerobic activity, 10% instruction and advice, and less than 1% as passive modalities. RMDQ, and Patient Specific Functional Score (PSFS), were completed pre and post and during follow-up			
Harts et al. [63]	65 male working army participants (age ~42 years) with CLBP	Participants underwent a 8 week intervention 2x/week for weeks 1-2 and 1x/week for weeks 3-8 using ILEX resistance training either as 'High Intensity' (HIT) or 'Low Intensity' (LIT) or a waiting list control (WLC). For HIT load was 50% of max isometric torque and 15-20 repetitions performed. Load was progressed by 2.5kg once the participant could complete more than 20 repetitions. Whether exercise was performed to MMF, sets, repetition duration and ROM for ILEX was not reported. For LIT load was 20% of max isometric torque and 15 or 20 repetitions performed. Whether exercise was performed to MMF, sets, repetition duration and ROM for ILEX was not reported. RMDQ, TSK and SF36 were completed pre and post. Follow-up was conducted at 6 and 9 months.	HIT group significantly improved in SF36 compared to both LIT and WLC (7%; $p < 0.05$). HIT group significantly improved in self-assessed decrease also compared to both LIT (39%; $p < 0.05$). No significant differences were found for any other variables.	RMDQ did not meet MCIC	No significant differences between groups were found for self-assessed improvement, RMDQ, or SF36 at 16 weeks follow-up.
Udermann et al. [82]	9 females (age 39.1±2.8 years, stature 164.2±1.6 cm, body mass 69.3±4.0 kg), 9 males (age 45.0±2.5 years, stature 180.6±1.6 cm, body mass 87.8±4.7 kg), with CLBP	9 participants underwent a 4 week intervention 1x/week using ILEX resistance training. Load was 50% of max isometric torque and a single set of 18-20 repetitions was performed to MMF through a full ROM using a slow controlled manner taking 2 seconds for the concentric phase and 4 seconds for the eccentric	Significant improvement in 6 of 8 subscales of the SF36 for both groups ($p < 0.05$) with no difference between groups.	N/A	N/A

		phase. Load was progressed by 5% once the participant could complete more than 20 repetitions. 9 participants underwent a 4 x/week intervention 2x/week using McKenzie therapy and home exercises every 2 hours. SF36 was completed pre and post.			
Vincent et al. [83]	49 obese participants (67% females, age ~68 years) with CLBP	18 Participants underwent a 4 month intervention 3x/week using ILEX resistance training. 17 Participants underwent a 4 month intervention 3x/week using ILEX resistance training and other resistance training exercises. ILEX and other exercises were performed for a single set using 60% of their 1 repetition for 15 repetitions attempting to produce a rating on the Borg scale of 16-18 Load was progressed 2% per week to maintain this. Whether exercise was performed to MMF, and ROM was not reported 14 participants acted as non-training waiting list controls who underwent standard care (including bodyweight resistance exercises, dietary information and information about back pain). ODI, RMDQ, Pain Catastrophising, TSK, and fear avoidance beliefs were completed at pre and post.	Significant group by time interactions for ODI (p 0.015), RMDQ ($p = 0.007$) and PCS ($p = 0.002$) in favour of the full body group.	Full body met ODI MCIC	Pairwise comparisons between groups were not reported.

Isolated Lumbar Extension = ILEX; Range of Motion = ROM; Momentary Muscular Failure = MMF; Chronic Low Back Pain = CLBP; Low Back Pain = LBP; Visual Analogue Pain Scale = VAS; Oswestry Disability Questionnaire = ODI; Roland Morris Disability Questionnaire = RMDQ; Tampa Scale for Kinesiophobia = TSK; Short Form 36 health questionnaire = SF36; Global Perceived Outcome = GPO; Medical Outcomes Study = MOS; Minimal Clinically Important Change = MCIC