Supplemental tables

Table A1. Summary of studies testing strength and endurance of the lumbar extensor musculature in LBP.

Reference	Participants	Testing	Results	Comments
Trunk Extension Studies				
Kankaanpaa et al. [37]	Healthy controls without history of LBP, $n = 15$ Middle aged women with CLBP, $n = 20$	Isometric MVC and isometric endurance to failure at 50%MVC during seated (knees 90°) restrained trunk extension	Significantly lower MVC and time endurance time to exhaustion in CLBP (both $p < 0.05$)	Those with previous lumbar surgery were excluded Age, height, body mass and BMI similar between groups
Alaranta et al. [48]	Never any pain, $n = 116$ Pain more than 12 months ago, $n = 46$ Pain during previous 12 month, no disability, $n = 166$ Disabling pain during previous 12 months, $n = 147$	Biering-Sorensen test	Significantly lower endurance time in those with history of LBP ($p < 0.05$)	
McNeil et al. [62]	Healthy controls, $n = 57$ CLBP patients, $n = 40$	Standing trunk extension/flexion MVC with pelvis restrained at top of iliac crest on superior edge of backboard using a belt across the anterior superior iliac spine, and bilateral restraints upon the iliac crests.	Both extension/flexion were lower in CLBP, however extension was reduced to a significantly greater degree shown by significantly lower extension/flexion ratios ($p < 0.01$)	Participants with sciatica & CLBP had significantly lower extension strength compared to both just CLBP participants and healthy controls ($p < 0.01$) – with the exception of comparison to females with CLBP (*ns*)
Addison & Schultz [63}	Healthy controls, $n = 57$ CLBP patients, $n = 33$	Standing trunk extension/flexion MVC with pelvis restrained at top of iliac crest on superior edge of backboard using a belt across the anterior superior iliac spine, and bilateral restraints upon the iliac crests.	Both extension/flexion were lower in CLBP, however extension was reduced to a significantly greater degree shown by significantly lower extension/flexion ratios ($p < 0.001$)	No differences between CLBP and an outpatient CLBP group suggesting common physical deficit despite differences in treatment seeking behaviour
Takemasa et al. [64]	Healthy controls without past history of LBP, $n = 126$ CLBP with or without organic lumbar lesions, $n = 123$	Isometric MVC during seated (knees 90°) restrained flexion/extension	Both flexion/extension were significantly lower in CLBP ($p < 0.05$), however extension was reduced to a significantly greater degree shown by significantly higher flexion/extension ratios in lesion group ($p < 0.01$)	No differences CLBP with or without organic lumbar lesions suggesting common physical deficit despite differences symptoms Age, height, body mass and BMI similar between groups
Handa et al. [65]	Healthy controls without past history of LBP, $n = 60$ CLBP patients, $n = 52$	Isometric MVC during seated (knees 90°) restrained flexion/extension	Isometric flexion did not significantly differ between groups, isometric extension was significantly lower in CLBP group ($p < 0.05$)	Age, height, body mass and BMI similar between groups

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Table A1. Continued.

Reference	Participants	Testing	Results	Comments
Suzuki & Endo [67]	Healthy controls without past history of LBP, $n=50$ CLBP patients with or without root impairment, $n=90$	Prone trunk extension MVC and flexion with legs both straight and bent at hips and knees with restraint belts across lower extremities	Both straight leg flexion, and trunk extension were significantly weaker in the CLBP group ($p<0.001$)	Age weight and height similar between groups
Leino et al. [69]	*Baseline participants* Participants with ''Good'' low back status, $n=578$ Participants with ''Intermediate'' low back status, $n=260$ Participants with ''Bad'' low back status, $n=64$ *Follow-up participants* Participants with ''Good'' low back status, $n=239$ Participants with ''Intermediate'' low back status, $n=203$ Participants with ''Bad'' low back status, $n=210$	Standing dynamic (baseline) and isometric (follow-up) trunk extension/flexion MVC with buttock and thighs against a supporting plate and ankles tied by a belt	At baseline dynamic flexion was significantly weaker in those with worse low back status ($p<0.01$) however dynamic extension was significantly weaker only in women ($p<0.05$) At follow-up isometric flexion was significantly weaker in only men with worse low back status ($p=0.01$) however isometric extension was significantly weaker in both men and women ($p<0.05$)	
Bayramoglu et al. [70]	Healthy controls with no history of LBP past 2 years, $n=20$ CLBP patients, $n=25$	Standing trunk extension/flexion MVC with stabilised knees and lower back	Both flexion and extension were significantly weaker in CLBP group ($p<0.05$)	Age and height similar between groups
Nicholaisen & Jorgensen [71]	(Group 1) LBP that made work impossible, $n=17$ (Group 2) LBP but not that hindered work, $n=28$ (Group 3) No history of LBP, $n=32$	Standing trunk extension/flexion MVC a and isometric extension endurance to exhaustion at 60%MVC with stabilised knees and lower back Biering-Sorensen test	No difference in extension/flexion strength between groups. Isometric endurance significantly lower for Group 1 compared to 2 3 in females and males ($p<0.05$) Endurance time significantly lower females for Biering-Sorenson test ($p<0.05$)	Age, weight, height and fat free mass similar between groups except for age being higher in group 1 and weight and fat free mass higher in group 1 for females
Holmstrom et al. [72]	(Group A) Healthy controls with no history of LBP, $n=42$ (Group B) CLBP patients with uncertain or negative clinical assessment, $n=75$ (Group C) CLBP patients with positive clinical assessment, $n=86$	Standing trunk extension/flexion MVC unrestrained lower extremities Biering-Sorensen test	No difference in extension/flexion strength between groups Extension/flexion ratio was significantly lower in Group C compared to A ($p<0.05$) Endurance time significantly lower in both Group C and B compared to A for Biering-Sorenson test ($p<0.01$)	Age, weight and height similar between groups
Salminen et al. [73]	Healthy children, $n=38$ Children with LBP, $n=31$ Children with LBP and sciatica, $n=7$	Biering-Sorensen test Sit up isometric test with knees at 90^0	Both flexion and extension endurance times were significantly lower in LBP groups ($p<0.05$) No difference between LBP and LBP with sciatica was found.	No differences CLBP with or without sciatica suggesting common physical deficit despite differences symptoms Age, sex, school matched between groups

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Table A1. Continued.

Reference	Participants	Testing	Results	Comments
Hultman et al. [74]	Healthy controls without history of LBP, $n=36$ Patients with intermittent LBP, $n=91$ CLBP patients, $n=21$	Seated isokinetic/isometric trunk extension/ flexion with thighs restrained Biering-Sorensen test	All variables, except isokinetic/isometric trunk flexion, were significantly lower in CLBP compared to healthy controls and intermittent LBP patients ($p<0.05$)	Those with previous lumbar surgery were excluded Age, height, body mass and body composition similar between groups
Parkkola et al. [75]	Healthy controls, $n=60$ CLBP patients suitable for active rehabilitation, $n=38$ CLBP patients with serious back problems suitable for moderate rehabilitation only, $n=10$	Standing isometric trunk extension/flexion MVC with chest, thighs and hips restrained	Extension/flexion MVCs showed a gradient between the three groups from higher to lower.	No statistical data reported Incidence of disc degeneration significantly higher in CLBP patients ($p<0.05$) Age, sex, employment and profession matched between groups and BMI similar
Mayer et al. [76]	Healthy controls without history of previous LBP, $n=19$ Postoperative spinal disc surgery patients, $n=46$	Isokinetic trunk extension/ flexion peak torque unrestrained lower extremities	Both extension and flexion were significantly lower in the postoperative group ($p<0.05$) with the greatest decrease being in extension strength	There was a significant correlation between trunk extensor strength and muscle density in postoperative patients No information on whether demographic characteristics differed between groups
Crossman et al [77]	Healthy controls without lasting >3 days in previous 12 months, $n=32$ CLBP patients, $n=35$	Standing trunk extension/ flexion isometric MVC unrestrained lower extremities Biering-Sorensen test	MVC and endurance time significantly lower in CLBP group ($p<0.05$)	Those with previous lumbar surgery were excluded Age, gender and all anthropometric characteristics similar between groups
Paasuke et al. [78]	Healthy controls, $n=12$ CLBP patients, $n=12$	EMG recorded bilaterally from lumbar paraspinal muscles at L3 level 3 cm from midline during Biering-Sorenson test to failure	Endurance time was significantly lower in the CLBP group ($p<0.05$)	Those with previous lumbar surgery were excluded Age and gender matched between participant groups Age, height, body mass and BMI similar among participant groups
Humphrey et al. [79]	Healthy controls without history of LBP in previous 5 years, $n=175$ CLBP patients, $n=145$ Participants with past history of LBP but no attack within previous 2 years, $n=30$	Back lift MVC	MVC significantly lower in CLBP patients compared to controls ($p<0.01$)	Those with previous lumbar surgery were excluded CLBP group was significantly older and had higher body mass and BMI than controls
Suuden et al. [80]	Healthy controls, $n=20$ CLBP patients, $n=20$	Biering-Sorenson test	Endurance time significantly lower for CLBP patients compared to controls ($p<0.05$)	Those with previous lumbar surgery were excluded Age, height and weight and BMI similar between groups
Lariviere et al. [81]	Healthy controls without history of LBP in previous year, $n=18$ CLBP patients, $n=18$	Dynamic roman chair trunk extensions to failure	Number of repetitions to failure were significantly less in CLBP patients compared to controls ($p<0.001$)	Those with previous lumbar surgery were excluded Age, height, weight and BMI similar between groups
Demoulin et al. [82]	Healthy controls without history of LBP in previous year, $n=10$ CLBP participants, $n=10$	Isometric MVC during seated (knees 90°) restrained trunk extension	Extension strength significantly weaker in CLBP ($p<0.05$)	Those with previous lumbar surgery were excluded

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Table A1. Continued.

Reference	Participants	Testing	Results	Comments
Balague et al. [86]	Children (10–16yrs) without history of LBP, $n=79$ Children (10–16yrs) with history of LBP, n 38	Standing isokinetic trunk extension/flexion peak torque unrestrained lower extremities	No significant differences for flexion or extension between groups at any age	
Suter & Lindsay [87]	Healthy controls, $n=16$ Golfers with CLBP, $n=25$	Biering-Sorenson test	No significant difference in endurance time between groups	Age, height and weight similar between groups
Da Silva et al. [88]	Healthy controls without history of LBP in previous year, $n=15$ CLBP patients, $n=13$	Standing trunk extension, prone trunk extension and back lift MVC	No differences between groups	Those with previous lumbar surgery were excluded Age, height and weight similar between groups
Lariviere et al. [89]	Healthy controls without LBP lasting 1 wk in previous year, $n=31$ CLBP patients, $n=27$	Standing trunk extension/flexion MVC and repetitions to failure (endurance time) with stabilised knees and lower back	No significant difference between health controls and CLBP patients for strength or endurance time Low predicted endurance time was associated with high pain catastrophising in CLBP patients ($p<0.01$)	Those with previous lumbar surgery were excluded Age, height, weight and BMI similar between groups
Renkawitz et al. [90]	Healthy tennis players without LBP, $n=36$ Tennis players with CLBP, $n=48$	Standing isometric trunk extension MVC with shoulders, pelvis and thighs hips restrained	No association between presence of CLBP and trunk extension strength in either univariate or multivariate logistic regressions	
Isolated Lumbar Extension				
Lariviere et al. [40]	Healthy controls without LBP lasting 1 wk in previous year, $n=18$ CLBP patients, $n=18$	Isolated lumbar extension MVC and number of repetition to failure at 60%MVC using customised dynamometer	No significant difference between groups	Those with previous lumbar surgery were excluded Age, body mass, height, BMI, body % and physical activity levels were similar between groups
Cassisi et al. [96]	Healthy controls without history of LBP, $n=12$ CLBP patients, $n=21$	Isolated lumbar extension MVC using MEDX	Lumbar extension significantly weaker in CLBP ($p=0.01$)	13 CLBP patients had undergone previous surgery though no effect upon lumbar extension strength was observed Age and height were similar between groups though body mass was greater in CLBP group
Holmes et al. [97]	Healthy geriatric female controls, $n=20$ CLBP geriatric female patients, $n=18$	Isolated lumbar extension MVC using MEDX	Lumbar extension significantly weaker in CLBP ($p<0.05$)	Age, height and weight similar between groups
Robinson et al. [98]	Healthy controls, $n=12$ CLBP patients (53% having had previous surgery), $n=16$	Isolated lumbar extension MVC using MEDX was performed and 60%MVC determined at full extension for further EMG analysis during isotonic trial (see table 3)	Absolute load used during isotonic trial was significantly lower in the CLBP group compared with the asymptomatic controls ($p<0.05$)	10 CLBP patients had undergone previous surgery Age, height and weight similar between groups
Nelson et al. [99]	CLBP patients, $n=895$	Isolated lumbar extension MVC using MEDX	CLBP baseline data was compared graphically to healthy norms from [53] and shown to considerably weaker.	Patients diagnoses included non-specific CLBP, degenerative disc/arthritic disease, lumbar disc syndrome or spondylolisthesis/spondylolysis

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Table A1. Continued.

Reference	Participants	Testing	Results	Comments
Mooney et al. [100]	Strip mine workers (90% reported prior LBP), $n = 197$	Isolated lumbar extension MVC using MEDX	Baseline data was compared graphically to healthy norms from [53] and shown to considerably weaker.	
Mooney et al. [101]	Healthy controls, $n = 8$ CLBP patients, $n = 8$	Isolated lumbar extension MVC using MEDX	CLBP baseline data was compared graphically to both healthy participants in the study and healthy norms from [53] and shown to be considerably weaker.	Patients showed evidence of degenerative disc disease
Boyce et al. [102]	Small manufacturing plant workers (53% reported LBP), $n = 20$	Isolated lumbar extension MVC using MEDX	Baseline data was compared graphically to healthy norms from [53] and shown to considerably weaker.	

Table A2. Summary of imaging and histochemical studies of the lumbar extensor musculature in LBP.

Reference	Participants	Testing	Results	Comments
Imaging Studies				
Hultman et al. [74]	Healthy controls without history of LBP, $n = 24$ Patients with intermittent LBP, $n = 40$ CLBP patients, $n = 21$	CSA and density of erector spinae using CT at L3 level	Muscle density was significantly lower in CLBP patients compared to both other groups ($p < 0.05$) CSA did not significantly differ between groups	Those with previous lumbar surgery were excluded Age, height, body mass and body composition similar between groups
Parkkola et al. [75]	Healthy controls, $n = 60$ CLBP patients suitable for active rehabilitation, $n = 38$ CLBP patients with serious back problems suitable for moderate rehabilitation only, $n = 10$	CSA, fat content and grading status graded using 4 classification system of psoas and back muscles (erector spinae and multifidus) using MRI at L4/L5 level	CSA was significantly lower in both CLBP groups compared with controls ($p < 0.001$) Back muscle status showed a gradient between the three groups from better to worse. It was significantly worse in severe CLBP patients compared with mild CLBP patients ($p < 0.05$) and healthy controls ($p < 0.001$), and was significantly worse in mild CLBP patients compared with controls also ($p < 0.05$) Psoas muscles did not differ between groups	Incidence of disc degeneration significantly higher in CLBP patients ($p < 0.05$) Age, sex, employment and profession matched between groups
Mayer et al. [76]	Healthy controls without history of previous LBP, $n = 19$ Postoperative spinal disc surgery patients, $n = 46$	CSA and muscle density of psoas, erector spinae, rectus abdominus and obliques using CT at L3	Non-significant trends towards reduced CSA in psoas and erector spinae were found in the postoperative group Muscle density of psoas and erector spinae was significantly lower in the postoperative group ($p < 0.001$)	There was a significant correlation between trunk extensor strength and muscle density in postoperative patients No information on whether demographic characteristics differed between groups

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Table A2. Continued.

Reference	Participants	Testing	Results	Comments
Kamaz et al. [91]	Healthy controls without LBP or leg pain, $n = 34$ CLBP patients, $n = 36$	CSA of total paraspinal, multifidus, quadratus lumborum, psoas and gluteus maximus muscles using CT at L4 upper and lower plates	CSA was significantly reduced in only paraspinal and multifidus at the lower plate in CLBP ($p < 0.01$) CSA was significantly reduced in only multifidus, psoas and quadratus lumborum at the upper plate in CLBP ($p = 0.05$) No significant differences between CSA of gluteus maximus	Those with previous lumbar surgery were excluded Age and BMI similar in both groups.
Sihvonen et al. [94]	LBP patients who underwent surgery for lumbar spinal stenosis and/or disc herniation 2–6 years prior with good recovery, $n = 14$ LBP patients who underwent surgery for lumbar spinal stenosis and/or disc herniation 2–6 years prior regarded as post-operatively failed, $n = 21$	Paraspinal muscle density at L4-L5 level using CT	Muscle density was significantly greater in the group with good recovery compared with the post-operatively failed group ($p < 0.01$)	Lumbar spinal stenosis and/or disc herniation confirmed by CT Age similar between groups
Mooney et al. [101]	Healthy controls, $n = 8$ CLBP patients, $n = 8$	Fatty infiltration and CSA of lumbar paraspinal musculature using MRI from L3 endplate to lower endplate of L5 and graded using 4 classification system	CLBP patients showed evidence of fatty infiltration compared with controls 5/8 showing severe All patients showed greater fatty infiltration of paraspinal muscles compared with any other lumbar muscles No difference in CSA between groups	No statistical data reported Patients showed evidence of degenerative disc disease
Hides et al. [103]	Healthy controls, $n = 51$ First episode acute LBP patients, $n = 26$	CSA of multifidus on left and right sides using real-time ultrasound at L2, L3, L4, L5 and S1	Asymmetry was significantly greater corresponding to level of symptoms in LBP patients compared with normal participant between-side differences ($p < 0.001$)	Only comparisons of between side differences were reported between LBP patients and normal participants. Manual extraction of data on CSA from figure 2 in ref [96] suggests that average CSA of asymptomatic side in LBP patients did not differ significantly from healthy participant's largest side. Age, height and weight similar between groups
Mannion et al. [106]	CLBP patients, $n = 59$	CSA of erector spinae, quadratus lumborum and psoas using MRI at L3/L4 and L4/L5 levels	CSA showed association with lean body mass and age, but no association with symptom duration	No healthy control group for comparisons Those with previous lumbar surgery were excluded

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Table A2. Continued.

Reference	Participants	Testing	Results	Comments
Mengiardi et al. [107]	Healthy controls without history of LBP in previous 2 years, $n = 25$ CLBP patients, $n = 25$	CSA of multifidus and longissimus fat content and semi-quantitative grading using 5 classification system using MRI at L4-L5 level	CLBP patients showed significantly greater fat content in the multifidus ($p < 0.05$) No difference found using semi-quantitative system	Those with previous lumbar surgery were excluded Age, sex and BMI matched between participant groups
Cooper et al. [111]	Recent onset LBP patients (symptoms less than 18 months), $n = 43$ CLBP patients (symptoms more than 18 months), $n = 44$	CSA of paraspinal and psoas muscles using CT at L4 normalised to L4 bone CSA	Normalised paraspinal and psoas CSAs significantly reduced in CLBP compared to recent onset group ($p < 0.05$)	All participants technically chronic as defined by Frymoyer [108] Lumbar surgery in preceding 18 months were excluded, though most CLBP patients included ($n = 31$) had undergone prior surgery CLBP participants also significantly older
Bouche et al. [112]	Post-discectomy patients pain free, $n = 18$ Post-discectomy patients with LBP, $n = 18$	Muscle CSA and fat CSA of total paraspinal, erector spinae, multifidus and psoas + iliac muscle using CT at L3, L4, and L5 normalised to L3 bone CSA	Muscle CSA of erector spinae and multifidus significantly smaller in pain patients ($p < 0.05$) Fat CSA significantly greater in psoas of pain patients ($p < 0.05$)	Level of operation was not found to be a significant factor and so suggests a general deconditioning of the lumbar musculature independent of surgery Age and BMI similar between groups
Danneels et al. [127]	Healthy controls without history of previous LBP, $n = 23$ CLBP patients, $n = 32$	Total CSA and muscle CSA of total paraspinal, erector spinae, multifidus and psoas muscles using CT at upper L3, and upper and lower L4 normalised	Total CSA of paraspinal and multifidus muscles significantly smaller at lower L4 in CLBP ($p < 0.05$) No significant difference for erector spinae or psoas	Those with previous lumbar surgery were excluded in addition to those who had participated in training for the lower back muscles in the previous 3 months Age, height, weight and activity similar between groups
Alaranta et al. [113]	CLBP patients, $n = 39$	Fat content of lumbar paraspinal musculature using CT at three lowest levels and 4 level classification system	Fat content was moderately positively associated with disability score on Oswestry index ($p < 0.05$) but not with age, sex, body mass, BMI, degree of disc degeneration, or facet joint osteoarthritis	Those with previous spinal fusion surgery were excluded however 16 patients had undergone previous surgery for lumbar disc herniation >1 year prior.
Kader et al [114]	CLBP patients, $n = 75$	Atrophy of the multifidus compared with normal results from [106] using MRI and 3 level classification system	80% of participants showed moderate of severe multifidus atrophy	Those with previous lumbar surgery were excluded Significant association between multifidus atrophy and leg pain ($p < 0.01$)

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Table A2. Continued.

Reference	Participants	Testing	Results	Comments
Barker et al. [115]	CLBP patients with unilateral pain, $n = 50$	CSA of left and right multifidus and psoas muscles using MRI at level of symptoms and one level above and below	CSA of both multifidus and psoas significantly smaller on symptomatic side at all levels ($p < 0.05$)	Those with previous lumbar surgery were excluded Multifdus atrophy consistently relatively greater than psoas atrophy at all levels Significant association between psoas atrophy and pain, nerve root compression and symptom duration. Significant association between multifidus atrophy and symptom duration
Kjaer et al. [116]	Adults aged 40 years, $n = 409$ (85% reporting LBP ever, 70% reporting LBP in previous year) Adolescents aged 13 years, $n = 439$ (41% reporting LBP ever, 22% reporting LBP in previous year)	Fat content of multifidus using MRI at 3 lower lumbar levels using 3 level classification system	Association between fat content of multifidus for LBP ever (Odds Ratio = 7.2) and LBP in physical year (Odds Ratio = 3.6) in adults. No association between fat content of multifidus in adolescents	Associations increased when controlling for effect moderators including gender, BMI, physical workload, leisure and sports activities.
Hyun et al. [117]	Healthy controls without lumbosacral radiculopathy or disc herniation, $n = 19$ LBP patients with unilateral lumbosacral radiculopathy, $n = 14$ LBP patients with disc herniation but no lumbosacral radiculopathy, $n = 25$	Total CSA and muscle CSA of mulitifidus using MRI at L3/L4, L4/L5, and L5/S1	Total CSA, muscle CSA and ratio of the two were significantly reduced in both LBP groups involved sides compared to controls at most levels ($p < 0.05$) and ratio at L3/L4 ($p < 0.05$) No difference between LBP groups for total CSA, muscle CSA and ratio of the two Ratio of involved side CSA to uninvolved side CSA was significantly different in radiculopathy patients compared to both controls and the other LBP patients ($p < 0.01$ to 0.05)	Those with previous lumbar surgery were excluded from LBP control group
Kalichman et al. [118]	Healthy controls without LBP in previous year, $n = 150$ Patients who had suffered from LBP of at least 1 month within previous year, $n = 37$	Density of erector spinae and multifidus muscles using CT at L3, L4, and L5	Muscle density was not associated with LBP Reduced muscle density was significantly associated with presence of facet joint osteoarthritis, spondylolisthesis and disc narrowing ($p < 0.05$)	

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Table A2. Continued.

Reference	Participants	Testing	Results	Comments
Hicks et al. [119]	Controls aged 70–79 years without LBP in previous year, $n = 861$ Patients with mild LBP in previous 12 months, $n = 244$ Patients with moderate LBP in previous 12 months, $n = 299$ Patients with severe/ extreme LBP in previous 12 months, $n = 111$	Total CSA and density of paraspinal, and lateral abdominal muscles using CT at L4-L5 level	Both non-adjusted and adjusted means for muscle density showed significant associations with the presence and severity of LBP for the paraspinal muscles ($p \leq 0.0001$), and lateral abdominals ($p < 0.05$).	
Kang et al.[128]	CLBP patients with lumbar degenerative kyphosis undergoing corrective surgery, $n = 54$ CLBP control patients, $n = 54$	CSA and muscle to disc CSA ratio of psoas, erector spinae and multifidus was assessed at L4/L5 level and fatty infiltration of psoas, erector spinae and multifidus assessed at L3/L4 using three grade classification using MRI	CSA and muscle to disc CSA ratios for all muscles were significantly lower in the lumbar degenerative kyphosis group compared with controls ($p < 0.001$) with regression analysis showing multifidus wasting to be most strongly associated ($p < 0.001$) Severe fatty infiltration was significantly more common in lumbar degenerative kyphosis compared to CLBP controls ($p < 0.05$)	No healthy control group for comparisons Those with previous lumbar surgery were excluded from CLBP control group Age and sex matched between groups and symptom durations were similar Body mass and BMI was significantly higher in CLBP controls No difference in degenerative changes (degenerative disc disease, herniation's, stenosis or spondylolithesis) between groups
Histochemical Studies				
Crossman et al [77]	Healthy controls without LBP lasting > 3 days in previous 12 months, $n = 32$ CLBP patients, $n = 35$	Percutaneous biopsy of paraspinal muscle (specific location not noted) for fibre CSAs and fibre typing.	No significant differences between groups for any fibre histochemical comparisons	Those with previous lumbar surgery were excluded Age, gender and all anthropometric characteristics similar between groups
Weber et al. [92]	LBP patients undergoing posterior surgery, $n = 61$ (posterior surgery for persistent pain Op1 $n = 43$, posterior surgery for removal of internal fixation Op2 $n = 32$)	Biopsy of multifidus at L3, L4, L5 or S1 level for fibre diameter, fibre typing and pathological changes	Pathological changes were common in biopsy specimens from Op1 Type II atrophy was associated with age and severity of pain in biopsy specimens from Op1 Patients undergoing Op2 showed significantly greater pathological changes compared with biopsy specimens from Op 1 ($p = 0.05$) Biopsy specimens were taken from 14 patients at the same level in both Op1 and Op2 with 70% of normal biopsies at Op1 showing alterations at Op2	No healthy control group for comparisons Muscular alterations were present in patients undergoing Op1 however surgery may have caused further alterations as presence of changes were increased in Op2

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Table A2. Continued.

Reference	Participants	Testing	Results	Comments
Rantanen et al [93]	Patients from ref [123] who underwent surgery for lumbar disc herniation 5 years prior, $n=18$	Biopsy of multifidus taken 1 cm laterally from spinous process of the level immediately below the previously herniated disc (L4/L5 and/or L5/S1) for fibre narrow diameter, fibre typing, atrophy/hypertrophy and pathological changes	No changes in fibre type distribution, atrophy/hypertrophy factors were noted compared with baseline Type I fibre size significantly increases	Level of herniation and thus biopsy did not influence results Patients with both 'positive' and 'negative' outcomes from original surgery were compared showing decreased pathological changes in 'positive' group compared with their persistence in 'negative' group
Sihvonen et al. [94]	LBP patients who underwent surgery for lumbar spinal stenosis and/or disc herniation 2–6 years prior with good recovery, $n=14$ LBP patients who underwent surgery for lumbar spinal stenosis and/or disc herniation 2–6 years prior regarded as post-operatively failed, $n=21$	Biopsy of paraspinal muscle taken from site of abnormal myelogram finding for fibre atrophy	Local denervation atrophy observed in all but one post operatively failed patients	Lumbar spinal stenosis and/or disc herniation confirmed as absent by CT Age similar between groups No statistical data reported
Mannion et al. [106]	CLBP patients, $n=59$	Biopsy of belly of lateral tract of left erector spinae at L3/L4 level for fibre CSA, fibre typing and pathological changes	Symptom duration was a strong predictor of both fibre type changes towards a more type IIx phenotype Pathological changes were common and significantly associated with age and showed a trend to association with symptom duration	No healthy control group for comparisons Those with previous lumbar surgery were excluded
Ford et al. [109]	Patients undergoing surgery for lumbar disc herniation reporting LBP duration between 3 and 52 weeks, $n=18$	Biopsy of erector spinae (sacrospinalis) 1 cm lateral to tip of spinous process and multifidus 1 cm from inferior border of lamina at L5 level for fibre typing, fibre narrow diameter and pathological changes	No differences between left and right sides Pathological changes were common but varied and not impacted by side of herniation	No healthy control group for comparisons Side of herniation did not affect results
Zhu et al. [120]	Patients undergoing surgery for lumbar disc herniation, $n=22$	Biopsy of erector spinae from side and level of herniation 1 cm lateral to top of spinous process for fibre typing, atrophy/hypertrophy and pathological changes	Proportion of fibres types for type I, type IIa and type IIb were 68%, 10.6% and 21.4% respectively Type II atrophy was common with type IIb most frequent and severe 18 patients showed evidence of pathological changes	No healthy control group for comparisons

(continued)

Table A2. Continued.

Reference	Participants	Testing	Results	Comments
Mannion et al. [121]	Healthy controls without history of LBP requiring time of work or doctors attention, $n = 29$ CLBP patients undergoing posterior surgery, $n = 31$ (First time operation $n = 22$, patients undergoing second operation $n = 9$)	Biopsy of belly of lateral tract of left erector spinae at L3 level for fibre narrow diameter, fibre typing and pathological changes	Smaller proportion of type I and greater proportion of type IIb fibres as both % and % fibre type area were found in CLBP patients compared to healthy controls ($p < 0.05$) Pathological changes did not differ between groups	Age, sex and body mass matched between participant groups
Fidler et al. [122]	Patients with LBP, $n = 17$ Cadavers within 24 hours of death, $n = 3$	Biopsy of multifidus from separated muscle cut transversely, taken during operation	Grouping of slow fibres appeared in addition to reduced CSA of fast fibres in LBP	No details on nature of operation No statistical data reported
Mattila et al [123]	Patients undergoing first time surgery for lumbar disc herniation, $n = 41$ Control participants without history of LBP undergoing autopsy within 48 hours of death, $n = 12$	Biopsy of multifidus taken during operation or autopsy at L4/L5 and L5/S1 levels for fibre narrow diameter, fibre typing, atrophy/hypertrophy and pathological changes	Relative numbers of type I and type II fibres did not correlate with age nor differ significantly between groups Pathological changes were significantly more frequent in patients compared to controls ($p < 0.01$)	Biopsy taken from deltoid to rule out systemic congenital myopathy Level of herniation and thus biopsy did not influence results
Zhao et al. [124]	LBP patients undergoing first time surgery for lumbar disc herniation, $n = 19$	Biopsy of multifidus taken during operation from transversospinal corner on both left and right sides at the level of herniation (L4/L5 or L5/S1) for fibre CSA, fibre narrow diameter, fibre typing and pathological changes	CSAs and diameters of both type I and type II fibres were significantly smaller on the side of herniation ($p < 0.05$) Strength factor (%fibre type x fibre CSA) of type II fibres was also lower on side of herniation ($p < 0.05$) Pathological changes were present in both sides but more severe on the side of herniation	No healthy control group for comparisons Location of pain symptoms was associated with muscle alterations
Bajek et al. [125]	Patients undergoing surgery for lumbar disc herniation, $n = 76$ Control participants without history of neuromuscular disease undergoing autopsy within 48 hours of sudden death, $n = 41$	Biopsy of multifidus on side of herniation and at level of herniation in patients (L3/L4, L4/L5, or L5/S1) and L4/L5 level in controls 1 cm lateral from midline deeper than the aponeurosis of erector spinae for fibre typing and fibre diameter	Greater proportion of type I and smaller proportion of type IIa type IIb fibres in patients compared with controls in males only ($p < 0.05$) Fibre diameter in type I fibres was significantly greater in paitents compared to controls ($p < 0.05$) and for type IIa and type IIb was significantly greater than controls for males only ($p < 0.05$)	Age was similar between groups

(continued)

Table A2. Continued.

Reference	Participants	Testing	Results	Comments
Yoshihara et al. [126]	LBP patients undergoing first time surgery for lumbar disc herniation, $n=29$	Biopsy of multifidus taken during operation immediately after start of surgery dissected from L4 and L5 muscle bands on both sides for fibre typing, fibre size and pathological changes	Fibre size of type 2 fibres was significantly smaller than type I at all biopsy sites Fibre size did not differ between sides at L4 for type I or type II fibres but fibre size was significantly smaller at L5 on side of herniation for both type I and type II fibres ($p<0.01$) No difference in fibre type proportions Pathological changes were present at all biopsy sites but only significantly different between sides, with greater frequency on side of herniation at L5	No healthy control group for comparisons No difference between level of biopsy

Table A3. Summary of studies testing fatigability with EMG of the lumbar extensor musculature in LBP.

Reference	Participants	Testing	Results	Comments
Kankaanpaa et al. [37]	Healthy controls without history of LBP, $n=15$ Middle aged women with CLBP, $n=20$	EMG recorded bilaterally from gluteus muscles and lumbar paraspinal muscles at L3/L4 and L5/S1 levels 2 cm laterally from midline of spinous process during isometric MVC and isometric endurance to failure at 50%MVC during seated (knees 90°) restrained trunk extension	Neither EMG amplitude or fatigue indices data differed between groups for the paraspinal muscles	Those with previous lumbar surgery were excluded Age, height, body mass and BMI similar between groups
Lariviere et al. [40]	Healthy controls without LBP lasting 1 wk in previous year, $n=18$ CLBP patients, $n=18$	EMG recorded bilaterally from gluteus maximus, biceps femoris and vastus medialis muscles and lumbar paraspinal muscles at L4, L3, L1, and T10 levels during isolated lumbar extension MVC and repetitions to failure at 60%MVC using customised dynamometer	None of the EMG fatigue indices data differed between groups for the paraspinal muscles	Those with previous lumbar surgery were excluded Age, body mass, height, BMI, body % and physical activity levels were similar between groups
Crossman et al [77]	Healthy controls without lasting >3 days in previous 12 months, $n=32$ CLBP patients, $n=35$	EMG recorded biltaerelly from lumbar paraspinal muscles at L4-L5 level during standing isometric trunk extension for 60 seconds at 60%MVC and during the Biering-Sorensen test	EMG fatigue indices were similar between groups for the Biering-Sorenson test and also the 60%MVC test	Those with previous lumbar surgery were excluded Age, gender and all anthropometric characteristics similar between groups

(continued)

Table A3. Continued.

Reference	Participants	Testing	Results	Comments
Paasuke et al. [78]	Healthy controls without history of LBP or LBP in previous year, $n=12$ CLBP patients, $n=12$	EMG recorded bilaterally from lumbar paraspinal muscles at L3 level 3 cm from midline during Biering-Sorenson test to failure	EMG indices of fatigue showed significantly greater fatigue in the CLBP group compared to controls ($p<0.05$)	Those with previous lumbar surgery were excluded Age and gender matched between participant groups Age, height, body mass and BMI were similar between participant groups
Humphrey et al. [79]	Healthy controls without history of LBP in previous 5 years, $n=175$ CLBP patients, $n=145$ Participants with past history of LBP but no attack within previous 2 years, $n=30$	EMG recorded bilaterally from lumbar paraspinal muscles at L4/L5 during a back lift test with 66.66%MVC for 30 seconds	EMG indices of fatigue showed significantly greater fatigue in the CLBP compared to controls ($p<0.05$) Logistic regression showed high sensitivity (0.65) and specificity (0.75) in classifying CLBP patients Past history participants could not be adequately discriminated from either group	Those with previous lumbar surgery were excluded CLBP group was significantly older and had higher body mass and BMI than controls
Suuden et al. [80]	Healthy controls, $n=20$ CLBP patients, $n=20$	EMG recorded bilaterally from lumbar paraspinal muscles at L3 3 cm from midline during Biering-Sorenson test to failure	No significant differences in EMG indices of fatigue between groups	Those with previous lumbar surgery were excluded Age, height and weight and BMI similar between groups
Lariviere et al. [81]	Healthy controls without history of LBP in previous year, $n=18$ CLBP patients, $n=18$	EMG recorded bilaterally from gluteus maximus, biceps femoris and lumbar paraspinal muscles at L4, L3, L1, and T10 levels during dynamic roman chair trunk extensions to failure	No significant differences in EMG indices of fatigue between groups	Those with previous lumbar surgery were excluded Age, height, weight and BMI similar between groups
Suter & Lindsay [87]	Healthy controls without history of LBP, $n=16$ Golfers with CLBP, $n=25$	EMG recorded bilaterally from lumbar paraspinal muscles at T12 and L4-L5 level 3 cm from midline during Biering-Sorenson test to failure	No significant difference in EMG fatigue indices between groups	Age, height and weight similar between groups
Da Silva et al. [88]	Healthy controls without history of LBP in previous year, $n=15$ CLBP patients, $n=13$	EMG recorded bilaterally from lumbar paraspinal muscles at T10, L1, L3, and L5 levels during standing trunk extension and back lift at 50%MVC for 60 seconds, and during Biering-Sorenson test for 60 seconds	No difference in EMG fatigue indices between groups	Those with previous lumbar surgery were excluded Age, height and weight similar between groups

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Table A3. Continued.

Reference	Participants	Testing	Results	Comments
Lariviere et al. [89]	Healthy controls without LBP lasting 1 wk in previous year, $n=31$ CLBP patients, $n=27$	EMG recorded bilaterally from gluteus maximus, biceps femoris and lumbar paraspinal muscles at L5, L3, L1, and T10 levels during standing trunk extension/flexion MVC and repetitions to failure (endurance time) with stabilised knees and lower back	EMG indices of fatigue showed significantly greater fatigue in CLBP patients with high catastrophising compared with CLBP patients with low catastrophising ($p<0.01$)	Those with previous lumbar surgery were excluded Age, height, weight and BMI similar between groups
Robinson et al. [98]	Healthy controls never treated for LBP and without LBP in previous year, $n=12$ CLBP patients (53% having had previous surgery), $n=16$	EMG recorded bilaterally from lumbar paraspinal muscles at L1-L2 level during isolated lumbar extension at 60%MVC in full extension for 12–13 repetitions	EMG amplitude in millivolts decreased across repetitions in asymptomatic participants compared with a significantly flatter curve in the CLBP group ($p<0.05$)	Age, height and weight similar between groups
Roy et al. [135]	Healthy controls, $n=12$ CLBP patients, $n=12$	EMG recorded bilaterally from lumbar paraspinal muscles at L1, L2 and L5 levels during standing isometric trunk extension for 60 seconds at 40%MVC, 60%MVC and 80%MVC	Discriminant analysis of EMG fatigue indices successfully classified 92% controls, 82% CLBP at 40%MVC, 67% controls, 75% CLBP at 60%MVC and 84% controls, 91% CLBP at 80% MVC	Those with previous lumbar surgery were excluded Age, height and weight similar between groups
Roy et al. [151]	Healthy controls without history of LBP, $n=42$ CLBP patients (43% having had previous surgery), $n=28$	EMG recorded bilaterally from lumbar paraspinal muscles at L1, L2 and L5 levels during standing isometric trunk extension for 30 seconds at 40%MVC and 80%MVC	Discriminant analysis of EMG fatigue indices successfully classified 85% CLBP patients and 86% healthy controls	CLBP patients heterogeneous with respect to symptoms and history (75% had disc herniation and 43% had undergone previous surgery)
Mayer et al. [154]	Healthy controls, $n=11$ CLBP patients, $n=10$	EMG recorded bilaterally from lumbar paraspinal muscles at L3 level 3 cm from midline during 10 isometric trunk extension holds on a roman chair lasting 15 seconds each and with 10 seconds rest between each hold	EMG indices of fatigue showed significantly greater fatigue in the CLBP group compared to controls ($p<0.01$)	Those with previous lumbar surgery at level of EMG placement were excluded Age and torso weight similar between groups
Peach & McGill [155]	Healthy controls without history of LBP in previous 2 years, $n=18$ CLBP patients, $n=21$	EMG recorded from lumbar paraspinal muscles at T9 level 5 cm from midline, L3 level 3 cm from midline, and L5 level 1–2 cm from midline respectively during semi-standing isometric trunk extension for 30 seconds at 60%MVC and then after a 60 second rest during a further 10 second extension at 60%MVC	EMG indices of fatigue showed significantly greater fatigue in the CLBP compared to controls ($p<0.05$) Discriminant analysis of EMG fatigue indices successfully classified 100% controls and 93.75% CLBP patients Logistic regression was equally powerful using two parameters with concordance of 92.4%	Age, height and weight similar between groups

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Table A3. Continued.

Reference	Participants	Testing	Results	Comments
Roy et al. [156]	Varsity rowers without LBP, $n = 17$ Varsity rowers with LBP in past year, $n = 6$	EMG recorded bilaterally from lumbar paraspinal muscles at L1, L2 and L5 levels during standing isometric trunk extension for 30 seconds at 80%MVC and then after a 60 second rest during a further 5 second extension at 80%MVC	Discriminant analysis of EMG fatigue indices successfully classified 93% controls and 100% LBP participants	Age, height and weight similar between groups
Biedermann et al. [157]	Healthy controls without history of LBP, $n = 22$ CLBP patients, $n = 27$	EMG recorded bilaterally from lumbar paraspinal muscles at L2-L3 and L4-L5 levels during standing with a 11.6 pound dumbbell held in outstretched arms for 45 seconds followed by a 5 minute recovery and the repetition of the 45 second trial – all adjusted for arm length differences	CLBP patients were classified into 'avoiders' or 'confronters' Discriminant analysis of EMG fatigue indices successfully classified 88.9% 'avoiders', 66.7% 'confronters' and 59.1% controls	Age, height, weight and arm length similar between groups Continuum of fatigue seen between avoiders > confronters > controls, however pain duration differed significantly between avoiders and confronters (8.57 ± 6.22 years and 1.60 ± 0.76 years respectively)
Klein et al. [158]	Varsity rowers without LBP, $n = 17$ Varsity rowers with LBP in past year, $n = 8$	EMG recorded bilaterally from lumbar paraspinal muscles at L1, L2 and L5 levels during standing isometric trunk extension for 30 seconds at 80%MVC and then further 10 second extensions at 80%MVC at 1 minute, 2 minutes, 5 minutes, 10 minutes and 15 minutes into recovery	Discriminant analysis of EMG fatigue indices showed most successful classification at 1 and 2 minute recovery, classifying for 1 and 2 minutes respectively 88% and 100% of LBP participants and 100% and 88% of controls	Age, height and weight similar between groups
Mannion et al. [159]	Healthy controls without history of LBP, $n = 10$ LBP patients, $n = 12$	EMG recorded bilaterally from lumbar paraspinal muscles at T10 and L3 level 3–4 cm from midline during Biering-Sorenson test for 60 seconds	MFS was greater in LBP group indicating greater fatigue but just failed to achieve significance ($p = 0.10$)	Age, height and weight similar between groups Mean values for MFS were similar to those in prospective study which did achieve significance in predicting first time LBP

Table A4. Summary of prospective studies of lumbar extensor musculature deconditioning in LBP.

Reference	Participants	Testing	Results	Comments
Biering-Sorenson [68]	Men aged between 30, 40, 50, and 60 years old, $n = 449$ Women aged between 30, 40, 50, and 60 years old	Biering-Sorensen test conducted at baseline 1 year follow-up with questionnaire concerning first time occurrence, recurrence or persistence of LBP	First time occurrence was significantly associated with low endurance time	
Leino et al. [69]	*Baseline participants* Participants with ''Good'' low back status, $n = 578$ Participants with ''Intermediate'' low back status, $n = 260$ Participants with ''Bad'' low back status, $n = 64$ *Follow-up participants* Participants with ''Good'' low back status, $n = 239$ Participants with ''Intermediate'' low back status, $n = 203$ Participants with ''Bad'' low back status, $n = 210$	Standing dynamic trunk extension/flexion maximum repetitions performed over 30 seconds with buttock and thighs against a supporting plate and ankles tied by a belt conducted at baseline Standing isometric trunk extension/flexion MVC with buttock and thighs against a supporting plate and ankles tied by a belt conducted at 10 year follow-up in addition to questionnaire and assessment of low back symptoms and status	Trunk strength was not predictive of low back symptoms or status at follow up.	
Luoto et al. [83]	Healthy participants without history of LBP in previous year at baseline, $n = 167$	Biering-Sorensen test and questionnaire regarding previous and present LBP conducted at baseline 75% of participants were available for follow-up at 1 year with the same questionnaire, $n = 126$	Endurance time was significantly associated with first time occurrence of LBP when adjusted for age, sex and occupation ($p < 0.05$) Endurance time broken into tertiles (poor, medium, good) showed a non- linear dose-response relationship with first time occurrence of LBP ($p < 0.04$) Relative odds ratio compared to 'good' for 'medium' and 'poor' were1.4 (95% CI 0.4–4.2) and 3.4 (95% CI 1.2–10.0) respectively	

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Table A4. Continued.

Reference	Participants	Testing	Results	Comments
Gibbons et al. [84]	Healthy participants without history of LBP in previous year at baseline, $n = 43$	Isokinetic back lift MVC, psychophysical back lift test, Biering-Sorensen test, CSA, proton-density weighted signal, and T2-weighted signal of erector spinae, quadratus lumborum, psoas major and total paraspinal muscle using MRI, and interview regarding previous and present LBP conducted at baseline Interviews regarding LBP were conducted at 1 year follow-up	Neither back lift, psychophysical back lift or endurance time differed between those with and without LBP at follow-up, nor where they associated with frequency of LBP at follow-up Neither CSA, proton-density weighted signal, or T2-weighted signal differed between those with and without LBP at follow-up, however, total paraspinal CSA, and proton-density weighted signal andT2-weighted signal of erector spinae, quadratus lumborum, psoas major were significantly associated with frequency of LBP at follow-up ($p < 0.05$)	
Mannion et al. [159]	Healthy nurses without history of LBP, $n = 200$	EMG recorded bilaterally from lumbar paraspinal muscles at T10 and L3 level 3–4 cm from midline during Biering-Sorenson test and maintenance of 80%MVC for 28 seconds at baseline Postal questionnaire regarding LBP conducted at 1 year follow-up	13% developed serious first time LBP during the follow-up period EMG indices of fatigue during Biering-Sorenson showed greater fatigue was significantly associated with development of first time LBP at follow-up ($p < 0.05$) however endurance time was not associated with first time LBP	
Rissanen et al. [163]	Participants from the Mini-Finland Health Survey, $n = 535$	Dynamic trunk extension/flexion maximum repetitions performed over 30 seconds with buttock and thighs against a supporting plate and ankles tied by a belt conducted at baseline Average 12 year follow-up to time until retirement due to work disablement, death or end of observation period for primary diagnosis as cause of work disability	At follow-up of 56 incident cases 15 were due to back disorders Adjusted relative risks in multiple models showed trunk extension performance significantly predicted back disorder disability risk ($p = 0.04–0.002$)	
Newton et al. [167]	Healthy participants without history of LBP, $n = 70$	Isokinetic trunk extension, flexion, rotation, and back lift MVC and psychophysical lift conducted at baseline 1 year follow-up with questionnaire concerning first time occurrence, recurrence or persistence of LBP	23% developed LBP during the follow-up period, yet at least 6 months after initial assessment in all cases None of the isokinetic measures differed between those who did and those who did not develop LBP	Those with previous lumbar surgery were excluded

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Table A4. Continued.

Reference	Participants	Testing	Results	Comments
Reimer et al. [168]	Healthy prospective order selector employees for 1989, $n=122$ Healthy prospective order selector employees for 1990, $n=122$ Healthy prospective order selector employees for 1991, $n=122$	Dynamic lift capacity, isokinetic trunk extension, flexion, rotation, and back lift MVC and psychophysical lift conducted at baseline to determine placement in employment as an order selector in a warehouse grocery distributor 2 year follow-up with questionnaire concerning first time occurrence, recurrence or persistence of LBP	After implementation of prospective evaluation for employment placement in 1989, incidence of low back injuries were significantly reduced by 32% in 1990 and 41% in 1991 ($p<0.001$)	
Batti'e et al. [169]	Employees working for a large aircraft manufacturer ($n=497$ reporting LBP in previous 10 years), $n=2178$	Isometric MVC for torso, arm and leg lift was conducted at baseline 4 year follow-up conducted for claims related to low back injuries or LBP	Participants with higher MVC for arm, leg and torso lift were at higher risk for LBP and low back injury ($p=0.01$, 0.03, and 0.26 respectively). When adjusted for age and sex however no association was present.	Due to an injury rate of 0.6% during torso lift testing it was discontinued. $n=495$ participants completed torso lift testing, $n=2158$ completed arm lift testing, and $n=2102$ completed leg lift testing
Lee et al. [170]	Healthy student participants without history of LBP, $n=67$	Isokinetic trunk extension, flexion, and rotation MVC conducted at baseline. 5 year follow-up concerning LBP incidence	27% developed first time LBP during the follow-up period Ratio of extension/flexion strength at baseline was significantly lower in participants who developed first time LBP, ($p<0.05$)	Age, height, weight and smoking habits similar between groups
Kujala et al. [171]	Healthy participants without history of LBP, $n=262$	Standing isometric trunk extension/flexion MVC was conducted at baseline 5 year follow-up with questionnaire was conducted regarding type, frequency, severity and functional limitations of LBP	47% developed first time LBP during the follow-up period, 11% of these reporting it as being of monthly frequency, 17% reporting radiating limb pain, and 2% having been hospitalised due to LBP Trunk extension/flexion was not associated with development of first time LBP	Age, weight and BMI similar between groups Height, occupational physical demands, and occupational musculoskeletal loading was significantly associated with first time LBP ($p<0.05$)

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Table A4. Continued.

Reference	Participants	Testing	Results	Comments
Chaffin [172]	Pre-employed plant workers in a variety of jobs involving manual lifting, $n=551$	Isometric MVC for torso, arm and leg lift in addition to job specific demands was conducted at baseline Preventative effectiveness of strength relative to job demands were evaluated by examining incidence and severity of low back injuries over an 18 month follow-up period Participants were grouped into tertiles relating to their individual strength relative to their job demands	As job strength requirements exceeded participant strength the incidence and severity of low back injuries increased at a ratio of 3:1 across the tertiles	
Keyserling [173]	Pre-employed plant workers applying for a range of 20 varied jobs, $n=71$	Isometric MVC for torso and arm lift, and push in/out in addition to job specific demands was conducted at baseline Preventative effectiveness of strength relative to job demands evaluated by placing of experimental ($n=20$) group into jobs matching strength whereas control group ($n=51$) were not Incidence of musculoskeletal injuries were evaluated over a 1 year follow-up period	During the follow-up period the control group experienced 19 incidences of musculoskeletal injuries compared to 0 in the experimental group	Age, weight and height similar between groups
Salminen et al. [174]	Healthy children, $n=38$ Children with LBP, $n=31$ Children with LBP and sciatica, $n=7$	Biering-Sorensen test, sit up isometric test with knees at 90^0 and MRI conducted at baseline 3 year follow-up period evaluating LBP ever, LBP in past 12 months, and recurrent/continuous LBP	Both flexion and extension endurance times were significantly lower in LBP groups ($p<0.05$) at baseline and follow-up yet endurance time was not predictive of development of first time LBP	Age, sex, school matched between groups
Sjolie & Ljunggren [175]	Healthy adolescents, $n=86$	Biering-Sorensen test and questionnaire regarding LBP conducted at baseline 3 year follow-up period with questionnaire was completed	High mobility/endurance time ratios were significantly associated with development of LBP at follow-up when adjusted for gender, LBP at baseline, and well-being and physical activity at follow-up (OR 1.5–1.9, 95% CI 1.1–3.2, $p<0.05$)	

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Table A4. Continued.

Reference	Participants	Testing	Results	Comments
Adams et al. [176]	Healthy nurses without history of LBP, $n=262$ Healthy nurses who had previously suffered with 'non-serious' LBP, $n=141$	Biering-Sorenson tets, isometric back lift MVC and back lift at 80%MVC for 20 seconds while EMG recorded from T10 and L3 conducted at baseline 3 year follow-up (every 6 months) conducted using questionnaire regarding LBP in previous 6 months	Endurance time at 3 year follow-up was significantly associated with development of serious LBP ($p<0.01$) and approached significance for any LBP ($p<0.058$) Neither back lift nor indices of fatigue were associated with development of LBP	
Mostardi et al. [177]	Healthy nurses without history of LBP, $n=171$	Isokinetic back lift MVC conducted at baseline Injury reports used to examine incidence of low back injury over 2 years follow-up	9% sustained low back injuries during the follow-up period There was no significant difference in strength at baseline between those who reported low back injury during follow-up and those who did not	
Cady et al. [178]	Healthy fire-fighters without LBP, $n=1652$	Isometric back lift MVC conducted at baseline Incidence of prior low back injuries examined subsequent to baseline measurements – no specific follow-up duration was noted Participants were split into percentiles for 'Most Fit' (84–100 percentile), 'Middle Fit' (17–83 percentile) and 'Least Fit' (0–16 percentile)	7.14% sustained low back injuries in the 'Least Fit' group, 3.19% sustained low back injuries in the 'Middle Fit' group, and 0.77% sustained low back injuries in the 'Most Fit' group	Mean age increased with decreasing fitness levels between the three groups
Mooney et al. [179]	Workers without history of LBP in a ship-building firm in the 3 highest Physical Demand Characteristic categories across 32 jobs, $n=152$	Isolated lumbar extension MVC using MEDX 2 year follow-up of low back injury and LBP claims	9% sustained low back injuries during the follow-up period the majority occurring in the heavy PDC category (64%) Isolated lumbar extension strength was not predictive of low back injuries and only 2 of those participants injured had below normal strength	Age, height and weight was similar amongst PDC categories and in those injured and uninjured Low back injury rates were significantly higher in heavy and very heavy PDC categories ($p<0.0001$)
Stevenson et al. [181]	Spinning operators from DuPont without history of LBP, $n=72$ Spinning operators from DuPont suffering from LBP in previous 2 years, $n=46$ Spinning operators from DuPont suffering from LBP in previous year, $n=31$	EMG recorded bilaterally from lumbar paraspinal muscles at T10 and L3 level 3–4 cm from midline during Biering-Sorenson test 2 year follow-up period at 6 month intervals for LBP experiences in previous 6 months	EMG indices of fatigues entered final model and were significantly predictive of LBP ($p=0.035$)	Other factors in final predictive model included age, peak thoracic acceleration, leg strength/endurance, however psychosocial factors were largely absent.

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Table A4. Continued.

Reference	Participants	Testing	Results	Comments
Heydari et al. [182]	Healthy participants classified as either 'No History of LBP', 'CLBP' or 'Past History of LBP', $n = 105$	EMG recorded bilaterally from lumbar paraspinal muscles at L4/L5 level during back lift test maintaining 2/3MVC for 30 seconds at baseline and follow-up 2 year follow-up participants were asked to classify themselves as 'worse', 'better, or 'the same'	At follow-up 76 classified themselves as 'the same', 13 'better' and 16 'worse' EMG indices of fatigue showed greater fatigue was significantly associated with development of first time LBP and with self-classification at follow-up ($p < 0.05$)	