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Title:

The efficacy of surface electromyographic biofeedback assisted stretching for the treatment of chronic low back pain: A case-series

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Conflict of interest

The are no conflicts of interest for any authors of this manuscript

ABSTRACT

Individuals with low back pain (LBP) commonly present with an impaired flexion-relaxation (FR) response, characterised as continued lumbar muscle activation at maximal voluntary flexion. The aim of the present investigation was to explore the effectiveness of a surface electromyographic assisted stretching (SEMGAS) programme in improving FR. Nine volunteers with chronic LBP and an impaired FR took part in weekly biofeedback SEMGAS sessions and performed a home-based stretching programme, for 5 weeks. FR, Oswestry Disability Index, Numeric Pain Rating Scale and Sit and Reach were recorded pre and post-intervention as well as at a 4- to 6-week follow-up. Of the nine participants included, three improved FR to statistically significant levels. These three participants also achieved a clinically important change in pain intensity scores. The results suggest SEMGAS may provide benefits to some individuals with chronic LBP and impaired FR, although larger scale investigation of SEMGAS alone is indicated.

Keywords: Flexion Relaxation, Chronic low back pain, Surface electromyography, SEMG-assisted stretching, Biofeedback, Pain intensity, Disability, Range of motion, Maximum voluntary flexion

INTRODUCTION

Flexion Relaxation (FR) is a muscle activation pattern where lumbar paraspinal muscle activity decreases near maximal voluntary flexion (MVF). The phenomenon was first described by Floyd and Silver (1951) and is consistently observable in pain free individuals (Kippers & Parker, 1984; Silver & Floyd, 1955).

FR is commonly attributed to the change in spinal load bearing structures from the muscles, which contract eccentrically to control the flexion movement, to the passive structures including spinal ligaments, discs and fascia (Colloca & Hinrichs, 2005; Kippers & Parker, 1984). As the posterior passive ligaments become increasingly tensioned during flexion, stretch receptors located in those posterior elements produce a reflex, which acts to inhibit the paraspinal muscles (McGill & Kippers, 1994; Schultz et al., 1985).

Individuals with chronic low back pain (LBP) commonly display abnormal FR, maintaining substantial muscle activity at MVF. Absent FR can reportedly identify 86-89% of chronic LBP patients from asymptomatic individuals (Ahern et al., 1988; P. Watson et al., 1997). While a reduced FR response appears to present as a positive adaptive response to acute injury, acting as a biological splint, aberrant muscle patterns and persistent activation may also partly contribute to the chronicity of chronic LBP. Although the FR response has been extensively employed as an instrument of assessment for evaluating treatment efficacy (Marshall & Murphy, 2006b; Neblett et al., 2010; Neblett et al., 2003), it has only recently received attention as a potential target of treatment. To date, the question as to whether restoration of FR can lead to improvements in other symptoms has not been addressed. While it must be acknowledged that FR does not always respond in accord with other outcome measures, it is also important to consider the complexities of LBP and the effects previous treatments have targeted (Ahern et al., 1990; Neblett et al., 2009; Triano & Schultz, 1987).

Recent investigation by Neblett et al., (2010) indicates that FR can be normalised with the addition of Surface Electromyography Assisted Stretching (SEMGAS) to an intensive functional restoration treatment programme, aiming to directly affect FR. Following the intervention, individuals with chronic LBP displayed myoelectric activity which was comparable with an asymptomatic control group. Although effective, the restoration of normal FR was observed following an intensive programme involving attendance between 2 and 5 days per week over a 2-month period. This level of intervention may not be acceptable for some people and it would be useful to identify whether a shorter and less intensive intervention may also result in improved FR. Therefore, the aim of the study was to evaluate the effectiveness of a SEMGAS programme at improving FR, pain intensity and disability, when prescribed in a typical clinical setting and when combined with a home-based stretching programme.

METHODS

Design

A prospective case series design was employed. Each participant undertook a daily home-based stretching protocol over 5 weeks. In each of the 5 weeks, participants attended the clinic for a 20-minute biofeedback session with one of the investigators (AM). At the completion of the 5-week period, participants were asked to return between 4 to 6 weeks later for follow-up measures. Continued participation in the stretching programme was at the participants own discretion.

Participants

Participants with chronic LBP were recruited from the general public over a 12-month period in response to advertising. Participants were included in the study if they were between 16 and 65 years of age, had experienced chronic LBP for a minimum of 3 months, and displayed an impaired FR (as identified at initial consultation, visually determined by observation of ‘more than usual’ activity occurring during terminal flexion). Participants were ineligible if they had a history of muscular or spinal pathology, class-two obesity, or were involved in another physical rehabilitation intervention. All participants gave written informed consent and the study was approved by the Unitec Research Ethics Committee (Approval No. 2011-1193).

Outcome Measures

Measurements of FR, disability (Oswestry Disability Index), flexibility (sit and reach) and pain intensity (numeric pain rating scale) were recorded at baseline, weekly throughout the study and again 4 to 6 weeks after completion (follow-up), where an additional measure, the Patient Global Impression of Change (PGIC), was also completed. The Revised Oswestry Disability Index (ODI) was used to measure functional status. The revised ODI has been shown to be reliable and valid in patients with low back pain (Fairbank & Pynsent, 2000; Fritz & Irrgang, 2001). The minimal clinically important difference (MCID) for the ODI is reportedly between 6 and 15 points (Burns et al., 2011; Fritz & Irrgang, 2001; Maughan & Lewis, 2010; Ostelo et al., 2008). For this study, a 10-point change was defined as a clinically relevant change. The Sit and Reach (SR) test was employed to assess the combined flexibility of the lumbar and hamstring muscles. A high concurrent validity when compared with laboratory equipment has been reported (Bozic et al., 2010). The ruler was offset (proximally) by 23 cm such that all measures are recorded as positive values. Previous studies suggest a MCID for SR to be a 4 cm change (López-Miñarro et al., 2012; López-Miñarro et al., 2009). The 11-point Numeric Pain Rating Scale (NPRS) was used to monitor pain intensity. The scale ranges from 0 (“no pain”) to 10 (“worst pain possible”). Each measure required the participant to rate the intensity of their pain over the past week on this scale. The MCID for the NPRS is consistently reported as 2 points (Childs et al., 2005; Ostelo et al., 2008; Wyrwich et al., 1999). The PGIC is measured with a 7-point scale

ranging from 1 (“No change, or condition has become worse”) to 7 (“A great deal better, a considerable improvement that has made all the difference”). PGIC scales are considered to be highly reliable ($r = 0.72$ to $r = 0.90$) (Stratford et al., 1994; Watson et al., 2005) and have strong correlations with patient satisfaction measures (Spearman correlation coefficients of 0.56 to 0.77) (Fischer et al., 1999). A score of 5 or greater is considered an improvement (Field et al., 2010; Hurst & Bolton, 2004).

Flexion Relaxation Instrumentation

Surface electromyographic (SEMG) data were collected using disposable foam electrodes (Covidien, REF 31118733), placed bilaterally on the muscle bellies of the lumbar paraspinal muscles at the L2 and L4 levels and approximately 2 cm lateral of the midline. Skin preparation involved gentle abrasion with fine-grade sandpaper (3M brand trace dot prep) and wiped with an alcohol swab, in order to reduce skin impedance to below 5 kilohms. Participants were asked to bend forward approximately 40 degrees whilst the four electrodes were placed and secured with medical tape, allowing for skin stretch during the bending movement. A reference electrode was placed at the olecranon process of the left elbow.

SEMG activity was recorded with a Power Lab/8SP and Octal bioamp (AD Instruments Ltd). Data were recorded with LabChart 7.2.1 (AD Instruments Ltd) at a sampling rate of 2 kHz and Finite Infinite Response (FIR) filters were used on the raw EMG data. Data were band-pass filtered between 20 Hz (high-pass FIR filter with a half-amplitude frequency of 20 Hz and transition width of 15 Hz) and 500 Hz (low-pass FIR filter with a half-amplitude frequency of 500 Hz and transition width of 100 Hz). When the power of 50 Hz (as assessed with a Fast Fourier Transformation) exceeded twice that of any other frequency band during the re-extension phase, a 50 Hz second-order notch filter with 32 dB attenuation was employed to filter noise artefact.

Flexion Relaxation Procedure

The movement required to assess FR consisted of the participant standing with arms relaxed, barefoot, and feet shoulder-width apart. An investigator (AM) explained and demonstrated the forward-bending movement to the participant. The instruction included starting in a comfortable standing position and maintaining straight, but unlocked knees. Participants were encouraged to maintain a regular breathing pattern as well as free hanging arms throughout the movement. Participants were instructed to “bend forwards towards their toes as far as they could go before feeling pain more than a ‘mild discomfort’ in their low back”. This movement was completed to a count of 3 s. Participants were then required to hold the position of maximal voluntary flexion (MVF) for 3 s, and were encouraged to “relax and let their body hang”. The re-extension movement returned the participant to the standing position over the final 3 s count. Data were recorded for three consecutive repetitions following three practice trials.

Treatment

SEMG Assisted Stretching

With electrodes placed and real-time visual feedback displayed on a monitor, participants were directed to “slowly flex their neck and bend forward with their knees slightly bent, as if to touch their toes”. When they felt a gentle stretch in their low back, they were to stop the bending movement and concentrate on relaxing the muscles in their back. The stretch was held for 30 s and completed three times, with data being recorded in real time. The researcher prompted the patient to relax with phrases such as “relax completely into the stretch”, “allow gravity to do the work and relax your body” and “focus on passive relaxation, rather than forcing the movement”.

Feedback included verbal feedback, visual feedback (slightly delayed as participants were unable to view the computer display from the fully flexed position), as well as verbal coaching and encouragement, as previously reported (Neblett et al., 2003).

The raw data recorded were discussed with the participant. Each participant was shown their elevated muscle activity during the target stretch, compared to normal FR. Participants were reassured the stretch was safe, were encouraged not to be fearful of the movement, and were reminded of the objective to achieve minimal activity of their lumbar muscles during the stretch.

Home Stretching

The home stretching programme was run concurrently over the 5-week intervention. Participants were asked to complete three repetitions of the above forward flexion stretch each day, holding the stretch for between 30 and 120 s. Participants were encouraged to be conscious of relaxing the muscles identified in the biofeedback sessions. A diary was provided to each participant to record self-reported adherence.

DATA ANALYSIS

SEMG Data Reduction

A ratio of maximal activity from re-extension and MVF (extension:relaxation ratio) was chosen as it has been reported to be highly correlated with clinical and musculoskeletal aspects of back pain (Neblett et al., 2009). At least 2 s (visually determined by the lead investigator to ensure artefact was avoided) of raw data from the middle of each movement phase were imported into Microsoft Excel 2010 for processing. Data were rectified and averaged using a moving 1s window Root Mean Square (RMS) calculation, where each window included 2000 raw samples and each successive window incremented by a single sample. The greatest 1 s RMS value from the re-extension and MVF phases was used to calculate the extension:relaxation ratio. At each session, the procedure was repeated and recorded three times, and the mean ratio of both left and right sides from the three recorded trials were used for further comparison and analysis.

Quantitative Analysis

The initial measures from each participant were used as baseline data. Comparisons were then made between baseline, post-intervention and follow-up using previously reported MCIDs. Change in FR was analysed using the Two Standard Deviation (2SD) Band method that is calculated from the baseline data of all participants. The baseline measures had a mean extension:relaxation ratio of 1.81 and standard deviation (SD) of 0.6. Therefore, a 2SD change of 1.2 in FR measures was considered significant. This procedure was used as it has the advantage of being sensitive to changes in variability across the phases of a single-system design (Nourbakhsh & Ottenbacher, 1994).

Owing to the small number of participants, the non-parametric Wilcoxon Signed-Rank Test was used to identify group changes between baseline and post intervention scores, as well as between baseline and follow-up scores for each of the four outcome measures. Statistical significance was set at the $p < .05$ level. Group means (μ) and medians (M) are reported, and where appropriate, SDs, 95% confidence intervals (CI) and effect sizes (Pearson's r) are presented.

RESULTS

Of the 40 people who responded to advertising, 16 met initial inclusion criteria, and of those, nine individuals displayed a visually detectable abnormal FR response and were invited to participate in the study (Table 1). All nine participants completed the five intervention sessions, however only seven participants completed all follow-up measures. Scheduling conflicts and a knee surgery were reported barriers for follow-up. The two participants unable to attend the follow-up session completed online versions of the ODI, NPRS and PGIC.

Table 1: Participant Demographics

Participant	Gender	Age (years)	BMI (kg/m ²)	Pain Duration (years)
1	F	55	33	10
2	F	47	30	8
3	F	46	34	25
4	M	62	30	5
5	F	42	21	4
6	F	60	25	5
7	F	44	19	6
8	M	21	28	2
9	F	59	23	20
Mean (SD)		48.4 (12.7)	27 (5.3)	9.4 (7.8)

Note: F=Female, M= Male, BMI=Body Mass Index

Overall Results

One participant (P8) made clinically important improvements in all outcome measures (maintaining all changes at follow-up; Table 2). One participant (P2) achieved MCID in all but one measure, and three participants (P3, P6, P7) improved in two of the four outcome measures. Two participants (P1, P4) improved only in flexibility measures. The remaining two participants (P5, P9) did not achieve MCID in any outcomes measures over the intervention period. No participants deteriorated by clinically important levels over the intervention period.

Table 2: Summary of Important Change from Baseline to Post Intervention

Participant	Flexion Relaxation	Pain Intensity	Disability	Sit and Reach	Total Outcomes Improved
1	N/C	N/C	N/C	I	1
2	I	I	I	N/C	3
3	N/C	N/C	I	I	2
4	N/C	N/C	N/C	I	1
5	N/C	N/C	N/C	N/C	0
6	N/C	I	N/C	I	2
7	I	I	N/C	N/C	2
8	I	I	I	I	4
9	N/C	N/C	N/C	N/C	0
Total Improved	3	4	3	5	15

Note: N/C = No Change, I = clinically important improvement.

Flexion Relaxation

Over the intervention period, three of the nine participants (P2, P7, and P8) achieved a significant improvement in FR ($\geq 2SD$) (Table 3). At follow-up, only one participant (P8) maintained a significant change. Two other participants (P1, P5), achieved a significant change only at follow-up.

When results for all participants are pooled, FR measures showed a non-significant improvement from baseline ($\mu = 1.81$, $SD = 0.6$; $M = 1.7$, $CI = 1.3 - 2.0$) to post-intervention ($\mu = 2.75$, $SD 1.7$; $M = 2.4$, $CI = 1.5$ to 3.8 , $T = 0$, $p = .14$, $r = -.49$). However, a significant overall improvement was observed from baseline to follow-up ($\mu=3.3$, $SD 2.2$; $M = 2.8$, $CI = 1.5$ to 5.7 , $T = 1$, $p = .03$, $r = -.83$).

Table 3: Flexion Relaxation Scores (Extension Relaxation Ratio)

Participant	Baseline Score	Post-Intervention Score	Baseline vs. Post Change	Follow-Up Score	Baseline vs. Follow-Up Change
1	3.2	4	0.8	5.7	2.5*
2	1.9	3.5	1.6*	2.9	1
3	2.2	1.3	0.8	n/a	n/a
4	1.7	2.4	0.7	n/a	n/a
5	1.8	1.3	-0.5	2.8	1
6	1.7	1.6	0.1	2.1	0.4
7	1.3	2.5	1.2*	1.5	0.2
8	1.2	6.5	5.3*	6.9	5.7*
9	1.3	1.6	0.3	1.3	0
Mean (SD)	1.81 (0.6)	2.75 (1.7)	1.3 (1.6)	3.3 (2.1)	1.5 (2) †

Note: * indicates a significant change of ≥ 1.6 ($\geq 2SD$ from baseline group mean of 0.6)

Pain Intensity

Four of the nine participants, (P2, P6, P7, P8) achieved a clinically important change in pain intensity (≥ 2 points) over the course of the intervention (Table 4). All four participants maintained these improvements at follow-up. Two additional participants (P1, P5) had achieved a MCID at follow-up despite reporting no change over the intervention period. Only one participant (P4) showed an important deterioration in pain intensity at follow-up compared to baseline and post intervention measures. However, at the time of the follow-up measures, this participant was awaiting an operation for his knee, which had recently increased in pain.

When the results from all participants are pooled, average pain intensity compared with baseline ($\mu = 4.7$, SD 1.3; M = 5, CI = 4 to 6), was significantly lower at post-intervention ($\mu = 2.89$, SD 2.3; M = 3, CI = 1 to 5, $T = 2$, $p = .02$, $r = -.80$) and even lower at follow up ($\mu = 2.7$, SD 2.0; M = 2, CI = 1.5 to 4, $T = 1$, $p = .04$, $r = -.69$).

Table 4: Pain Intensity (NPRS scores)

Participant	Baseline Score	Post-Intervention Score	Baseline vs. Post Change	Follow Up Score	Baseline vs. Follow Up Change
1	6	6	0	2	4*
2	4	1	-3*	2	-2*
3	2	1	-1	2	0
4	5	4	-1	7	2*
5	6	6	0	4	-2*
6	5	1	-4*	1	-4*
7	6	4	-2*	4	-2*
8	4	0	-4*	0	-4*
9	4	3	-1	3	-1
Mean (SD)	4.7 (1.3)	2.9 (2.3)	-1.8 (1.6) †	2.8 (2)	-1.9 (2) †

Note: * indicates a clinically important change of 2 or more points, † indicated $p < .05$

Functional Disability

Clinically important improvements in ODI (≥ 10 points) were achieved in three of the nine participants (P2, P3, P8) at post intervention, compared to baseline scores (Table 5). These three participants maintained improvements at follow-up.

Two participants (P7, P9) reported more disability post-intervention compared to baseline (although this change did not achieve MCID). Participant four deteriorated from post-intervention to follow-up to the level of MCID, however this was the aforementioned participant scheduled for knee surgery.

The pooled results of all participants showed average ODI scores were significantly higher at baseline ($\mu = 20.4$, SD 9.2; $M = 22$, CI = 12 to 29) than at post-intervention ($\mu = 12$, SD 7.7; $M = 12$, CI = 6 to 17, $T = 1$, $p = .035$, $r = -.70$). However, differences between baseline and follow up were not statistically significant ($\mu = 13.8$, SD 9.8; $M = 14$, CI = 7 to 21, $T = 1$, $p = .141$, $r = -.49$).

Table 5: Disability (ODI scores)

Participant	Baseline Score	Post-Intervention Score	Baseline vs. Post Change	Follow Up Score	Baseline vs. Follow Up Change
1	22	16	-6	14	-8
2	34	10	-24*	8	-26*
3	32	8	-24*	14	-18*
4	26	18	-8	28	2
5	14	14	0	14	0
6	10	4	-6	6	-4
7	8	12	4	10	2
8	16	0	-16*	0	-16*
9	22	26	4	30	8
Mean (SD)	20.4 (9.2)	12 (7.7)	10.2 (8.9) †	13.8 (9.8)	6.7 (11.2)

Note: * indicates an important change of 10 or more points; † indicates $p < .05$

Flexibility

Over the intervention period, five participants (P1, P3, P4, P6, P8) achieved a clinically important change in flexibility as defined by a 4 cm change in SR scores (Table 6). Of these five, three participants (P1, P6, P8) maintained an important improvement at follow-up. The two remaining participants (P3, P4) were not available for follow-up measures. Compared to the baseline score, participant nine deteriorated by important levels at follow-up.

When the results of all participants were pooled, flexibility improved significantly from baseline ($\mu = 19.2$, SD 13.9; M = 19, CI = 6 to 32), to post-intervention ($\mu = 24.6$, SD 11.8; M = 27, CI = 13.5 to 36.3, $T = 0$ $p = .02$, $r = -.77$), however failed to maintain significance at follow-up ($\mu = 28.2$, SD 9.0; M = 25, CI = 24 to 36, $T = 1$, $p = .207$, $r = -.48$).

Table 6: Sit and Reach scores (cm)

Participant	Baseline Score	Post-Intervention Score	Baseline vs. Post Change	Follow Up Score	Baseline vs. Follow Up Change
1	13	28.5	15.5*	25	12*
2	33	36.5	3.5	31	-2
3	1	7	6*	n/a	n/a
4	1	9	8*	n/a	n/a
5	40	39	-1	42	2
6	31	36	5*	36	5*
7	24	27	3	24	0
8	11	21	10*	25	14*
9	19	18	-1	14	-4.5*
Mean (SD)	19.2 (13.9)	24.6 (11.7)	5.4 (5.3) [†]	28.2 (9)	3.7 (6.9)

Note: * indicates an important change of 4 cm or more, [†] indicates $p < 0.05$

Patients Global Impression of Change

At the completion of the study, four of the nine participants (P2, P3, P6, P8) reported their progress over the intervention as having at least a 'moderate and noticeable change' in symptoms, scoring 5 or over on the PGIC. Each of the individual four participants achieved MCID for at least two of the four outcome measures. Only two of the participants reporting at least a moderate change showed significant improvement in FR measures over the study (P2 and P8).

Of the five participants who reported a change in PGIC that was not meaningful, participant seven showed FR that was significantly improved over the study period and two participants (P1, P5) significantly improved FR from post-intervention to follow-up.

Adherence to Home Stretching

All participants reported at least 90% adherence, with five participants reporting 100%. The most days missed over the intervention by any participant were 3 out of approximately 35 days (P2).

DISCUSSION

The primary aim of this study was to investigate if a SEMGAS programme would improve FR in individuals with chronic LBP. A secondary aim was to investigate if improved FR was associated with improved pain intensity, disability and sit and reach measures. The results from the present study were not unanimous, however, over the course of the intervention three of the nine participants significantly improved FR, with all three achieving clinically important changes in pain intensity scores and two improving in perceived disability.

FR and Pain are Related

Impaired FR has been attributed to a mechanism of continuous paraspinal contraction, which is common in patients with current pain (Geisser et al., 2004; Sihvonen et al., 1998; Thomas & France, 2008). We hypothesised that the continued paraspinal muscle activity may actually contribute to the pain, by preventing adequate muscle recovery. Therefore, we expect that decreased pain intensity scores will accompany improved FR. The current study supports the positive association between pain intensity and FR, as all participants improving FR also improved pain intensity scores. It is not possible to determine if changes in FR caused a decrease in pain intensity or if the intervention had indirectly affected pain and caused a subsequent improvement in FR. The pain-spasm model described by Travell et al (1942) predicts increased muscle activity is persistent in chronic LBP patients. Limited recovery time is implicated in pain production, presumably owing to the accumulation of muscle by-products from the continued contraction (Kaufman et al., 1983; Mense, 1993). Utilising SEMGAS and training the muscles to relax effectively allows for appropriate paraspinal relaxation and repair. Pain intensity potentially reduces as muscle function begins to normalise. Although the current study included a small sample (n=9), the association between improved FR and improved pain intensity appears strong in responding individuals, in that all three participants that improved FR also improved pain intensity measures. It may be that these three participants had aberrant muscle activity patterns that perpetuated the pain cycle, while this may not have been a factor for the other 6 participants. Indeed, the mixed evidence in regards to the pain-spasm model indicates that this is not ubiquitous with LBP (Hodges, 2011). The results of the present study reflect the recent studies by Neblett and colleagues who observed significant improvements in pain intensity when SEMGAS was employed concurrently with a comprehensive functional restoration programme (Neblett et al., 2003; Neblett et al., 2009).

Although improved pain intensity was consistently observed with improved FR, one participant improved in pain intensity scores but not FR. Although this finding contrasts the protective splinting behaviour (Main & Waddell, 1991; Sullivan et al., 2001), the finding is more in line with other reports of low associations between improved FR and improved pain measures, especially in individuals with chronic LBP (Ahern et al.,

1990; Neblett et al., 2009; Triano & Schultz, 1987). However, researchers have typically utilised rehabilitation modalities that have not specifically addressed FR, and have instead employed FR as an outcome measure (Marshall & Murphy, 2008; McGorry & Lin, 2012; Neblett et al., 2009; Neblett et al., 2003; Owens et al., 2011; Sihvonen et al., 1991; P. Watson et al., 1997). Directing an intervention to specifically affect FR has only recently been explored. The current study and Neblett et al.'s 2010 study are the only investigations aimed at directly improving FR. As SEMGAS aims to directly affect FR, the current results suggest that improved FR may influence pain intensity scores.

Clinical Importance

Over the intervention, three participants achieved an important improvement in disability measures, two of which also improved in FR measures. Participant seven improved FR but had a (clinically un-important) deterioration in disability. Unsurprisingly, all three improving disability, reported important improvement in PGIC measures.

The intervention appeared to be effective in reducing perceptions of disability for some (three) of the participants in the study. Interestingly, improvements in FR were not required for all three of these participants to achieve this improvement, as only two of the three displayed an improved FR. These results reflect the multifactorial complexity of disability, in that improvement in a single outcome measure can seldom be expected to strongly correlate with an improved disability.

The participant reporting the largest improvement over the intervention (P8), significantly improved in all measured outcomes, was the youngest participant (21 years) involved in the study, and had symptoms for the shortest duration (2 years). P8 also started with the lowest baseline FR ratio value, indicating a significant maladaptive neuromuscular response to pain. However, P5 was the second youngest (42 years) with the second shortest duration of symptoms (4 years), yet failed to achieve any significant changes. Although it is possible that age and symptom duration are associated with outcomes, especially when considering the significant age gap between the youngest and next youngest participants, confident inferences cannot be made from this case-series.

Range of Motion and Flexion Relaxation

Due to the inclusion of a stretching component in the SEMGAS programme, it was anticipated that range of motion (ROM) would improve in participants following the intervention. Flexibility was improved to clinically relevant levels in the majority ($n=5/8$) of participants over the intervention period. However these improvements appeared to be poorly associated with any other outcome measures in the current study and only one of these individuals achieved improvement in FR. However, all those that achieved FR, also achieved normal SR scores following the intervention. Recent literature supports this observation with reported high specificity in predicting normal ROM in those who achieve FR (up to 100%), with considerably lower sensitivity as having normal ROM does not predict normal FR (Neblett et al., 2003; Neblett et al., 2009). Participants with normal ROM but abnormal FR somewhat contradict the 'protective'

role of the increased paraspinal activity, as despite improved ROM, participants still fail to reduce muscular 'guarding'. In their 1999 study, Zedka and associates found elevated muscle tone in painful situations, in spite of controlling for guarding and producing movements (Zedka et al., 1999). It therefore seems likely that improved FR cannot be exclusively attributed to changes in ROM. An altered neuromuscular response, probably mediated by pain, is at least in part responsible for observed changes.

Dose

In order to contain costs and improve efficiency of treatment, it is beneficial to identify the lowest effective dose of a treatment at improving quality of life. Previous studies investigating the effect of various interventions on FR measures have ranged in dose from a single session, up to 240 hours (Lalanne et al., 2009; Marshall & Murphy, 2008; Neblett et al., 2010; Ritvanen et al., 2007). The present intervention was specifically designed to be brief, involving a total of only two hours of contact time over a five-week period. The results of this study found that three of nine participants had significant improvements in FR, as well as in the majority of outcome measures over the intervention. Therefore a less intensive intervention such as the one described may be effective in improving FR, pain intensity, disability and sit and reach in some patients with chronic LBP. Conversely, a more lengthy intervention period may have been required to achieve an appreciable change in other participants. In Marshall and Murphy's (2008) study, researchers were able to identify FR improvement after 4 weeks of involvement in active exercise, which plateaued by week 8. Neblett et al.'s 2010 study, normalised FR in chronic LBP patients in an average of 2.4 (SD 1.4) SEMGAS sessions, with a maximum of six sessions required to attain FR (session duration was not described). However, 10 of the 47 participants were unable to achieve FR despite multiple sessions.

CONCLUSION

The findings of this study should be interpreted cautiously given the limitations inherent in case-series designs (Grimes & Schulz, 2002). The small number of cases and heterogenous profile of participants precludes generalization beyond the study. However, this case-series does demonstrate that SEMGAS used alone, with a limited dose, can be effective at improving FR in some individuals with chronic LBP. While this study did not identify convincing predictors of treatment effectiveness, it appeared that improvements in FR were more closely related to improvements in pain than ROM. This indicates an adaptation of the neural, rather than behavioural, component of the FR task. It is plausible that this intervention was effective only in individuals where the increased muscle activity was contributing to soreness. Indeed, the evidence for the pain-spasm model is insufficient to generalise to all individuals (Hodges 2011). However, decades of mixed evidence (Roland 1986) suggests that this aberrant neuromuscular adaptation to pain could potentially be a factor in a minority of individuals, and perhaps it is these patients that may best benefit from SEMGAS. A controlled trial to investigate such a hypothesis appears well justified.

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