Clinical Rehabilitation 2000; **14**: 631–640

An evaluation of a new pattern of electrical stimulation as a treatment for urinary stress incontinence: a randomized, double-blind, controlled trial

SM Jeyaseelan Centre for Rehabilitation Science, University of Manchester, **EJ Haslam** Chorley & South Ribble District General Hospital, **J Winstanley** Department of Nursing, Midwifery & Health Visiting, University of Manchester, **BH Roe** Institute of Human Ageing, University of Liverpool and **JA Oldham** Centre for Rehabilitation Science, University of Manchester, Manchester, UK

Received 5th May 2000; returned for revisions 23rd June 2000; revised manuscript accepted 3rd August 2000.

Objective: To evaluate a new pattern of electrical of electrical stimulation as a treatment for stress incontinence.
Design: A randomized, double-blind, controlled trial.
Setting: The study took place on three clinical sites.
Subjects: Patients ($n = 27$) with urodynamically proven stress incontinence recruited via consultant referral.
Interventions: Patients were randomly allocated to one of two groups: the new pattern of stimulation or sham stimulation.
Main outcome measures: Patients were assessed pre, mid and post treatment using: perineometry, digital assessment and pad testing. The following were only used pre and post treatment: seven-day frequency/volume chart, SF-36, the Incontinence Impact Questionnaire and the Urogenital Distress Inventory.
Results: No significant between-group differences were highlighted except when quality of life was assessed with the Urogenital Distress Inventory ($p = 0.01$). A significant reduction in scores was observed in the stimulation group ($p = 0.03$) However, improvements were seen in both the strength and endurance characteristics of the pelvic floor musculature, although these changes were not translated into a reduction in symptoms.
Conclusion: Although promising, the improvement in pelvic floor function did not result in a reduction in symptoms in all patients. Further research is required to investigate the effects of the new stimulation in combination with pelvic floor exercises and to compare the new stimulation pattern with existing forms of electrical stimulation.

Address for correspondence: SM Jeyaseelan, Centre for Rehabilitation Science, University of Manchester, Central Manchester Healthcare Trust, Oxford Road, Manchester M13 9WL, UK. e-mail: mone5smj@fs1.nu.man.ac.uk

0269–2155(00)CR372OA

Introduction

Urinary incontinence is defined as 'a condition in which the involuntary loss of urine is a social or hygienic problem and is objectively demonstrable'. In the UK 3 million people suffer from incontinence. Brocklehurst[1] reviewed the findings of a MORI poll and reported that of the women interviewed ($n = 2124$), 14% had been incontinent of urine. Prevalence has also been shown to increase with age,[2] and a report of the Royal College of Physicians based on the nine major prevalence studies found that there was a prevalence of urinary incontinence of 5% and 20% for women aged between 15 and 44 and over 65, respectively.[3] The cost to the NHS of caring for people with incontinence is estimated at £68 million.[4] Stress incontinence is one of the most prevalent forms of incontinence in women[5] and is characterized by the involuntary loss of urine during activities that involve a sudden increase in intra-abdominal pressure, such as laughing, coughing or strenuous exercise. Furthermore, for those suffering with incontinence, its effects on the quality of life can be considerable.

There are various methods of treating stress incontinence, ranging from surgery and pharmacological intervention to conservative treatment modalities. The two most commonly used forms of conservative treatment for stress incontinence are electrical stimulation and pelvic floor exercises.[6] However, current forms of electrotherapy involve the use of uniform frequency stimulation that contains only one component addressing either the endurance or power-generating ability of the muscle, each at the expense of each other.

As skeletal muscle needs both endurance and power-generating properties, it is unacceptable when treating patients with pelvic floor muscle weakness to use electrical muscle stimulation that will only enhance either strength or endurance. These concerns were initially addressed with the development of more physiological patterns of electrical stimulation, such as Patterned Neuromuscular Stimulation.[7,8] This involved the delivery of several frequencies mimicking motor nerve firing patterns during the stimulation period.

This type of stimulation also has its drawbacks, due primarily to overstimulation of the muscle. In order to address these concerns it is apparent that stimulation regimens require strengthening and endurance components whilst keeping the number of impulses delivered to a muscle to a minimum, thus preventing premature muscle fatigue.[9] Research has suggested that for endurance characteristics to be enhanced without a loss in force-producing capacity a very low stimulation frequency (i.e. less than 10 Hz) is required.[10,11] In addition to this very low-frequency component a high frequency component is also required to improve the force-generating ability of the muscle. Unfortunately, high-frequency stimulation is often associated with premature fatigue. This can, however, be minimized by maximizing the force production per impulse, which can be achieved by incorporating a doublet at the start of the stimulation pattern.[12,13]

This work has now been taken further and a new pattern of electrical stimulation has been developed which is believed to incorporate these essential components to increase both strength and endurance characteristics of skeletal muscle without causing premature fatigue.

The aim of this study is to compare the effects of this new type of electrostimulation with sham stimulation as a means of rehabilitating the pelvic floor musculature, thereby relieving/eliminating the symptoms of stress incontinence.

Methods

The study was performed on three clinical sites (ethical approval was obtained for all three sites) where trained clinicians were responsible for performing all outcome assessments and were not aware of which group the patient was in. The investigator was responsible for randomly allocating all subjects to treatment groups, assigning stimulators and monitoring treatment.

Twenty-seven patients were recruited via consultant referral provided they fulfilled the criteria summarized below:

Inclusion criteria:

Urodynamically proven stress incontinence

No neurological conditions diagnosed by consultant

Exclusion criteria

Previous electrical stimulation for stress incontinence
Prolapse
Pregnancy
Pacemakers and cardiomyopathy
Abnormal urological/gynaecological findings
Urinary tract/vaginal infection
Recent pelvic floor surgery (within the last six months).

Following the receipt of informed consent, patients were randomly allocated to one of two groups (sham stimulation or the new pattern of stimulation) using a computer-generated table of random numbers.

Sample size calculations based on a study by Sand *et al.*[14] with the 20-minute pad test taken as the primary outcome measure showed that a sample size of 12 in each group would have a 90% chance of detecting a difference in means of –32.2 g (the difference between the treatment group mean of –29.9 g and the control group mean of 2.3 g) assuming that the common standard deviation is 23.048 using a two-group *t*-test with a 0.05 two-sided significance level.

The following tests were performed before, during and after the treatment period.

- Digital vaginal assessment of pelvic floor muscle strength using the modified Oxford grading scale.[15] The scale ranges from 0 to 15, with 0 indicating very weak pelvic floor musculature.
- Assessment of vaginal muscle strength and endurance using the PRS 9300 perineometer (Incare Medical Products, Hollister Inc., Illinois, USA). The absolute minimum was 0 cmH_2O, but there was no predetermined maximum. Endurance was also expressed in cmH_2O as the decline in strength during a series of intermittent contractions was measured to determine endurance.
- The one-hour pad test as recommended by the International Continence Society (ICS).[16]

The following tests were only performed pre and post treatment.

- Seven-day frequency/volume charts.[17] From this, the number of leaks per week were noted.
- Generic (SF-36) and condition-specific (Incontinence Impact Questionnaire and Urogenital Distress Inventory) quality of life questionnaires.[18–20] For the Incontinence Impact Questionnaire (IIQ) and Urogenital Distress Inventory (UDI) scores range from 0 (not bothered by incontinence) to 100 (greatly bothered by incontinence).

Treatment regimen

A portable stimulator (PS1, Dynamic Medical Instruments Ltd., Wigan, UK) attached to a Periform Probe (Neen Healthcare, Dereham, UK) was used to deliver both sham stimulation and the new pattern of stimulation. All patients were required to use the stimulator for an hour a day for eight weeks (except when menstruating).

New stimulation pattern

The stimulation protocol consisted of a background low frequency (to target slow twitch fibres) and intermediate frequency with an initial doublet (to target fast twitch fibres). A low number of impulses within the high-frequency component and adequate rest periods between stimulus trains were used to reduce premature fatigue. The electrostimulation technique is as described by Oldham (International Patent Publication WO98/47357).[21]

Sham stimulation

Placebo stimulation was used as a control and given to the second group of patients. The sham stimulation consisted of one 250-μs impulse every minute for 60 minutes. This method of stimulation has been proven to have no physiological effect on muscle.[22]

Data collected from all three time points (pre, mid and post) were analysed using a repeated measures ANOVA, and any significant differences highlighted were further investigated using the paired *t*-test. Where appropriate, the non-parametric equivalents of these tests, i.e. the Friedman and the Wilcoxon signed ranks tests, were used.

Results

Twenty-seven women in total were recruited into the study. Twenty-four women completed the

trial. Three women withdrew from the study (see Figure 1) as they felt the stimulation protocol was too demanding. They then received conventional physiotherapy treatment and their data were not included in the analysis. On analysis of the pre-treatment data no statistically significant differences ($p > 0.05$) were found between the two treatment groups, with respect to their initial baseline assessments (see Table 1).

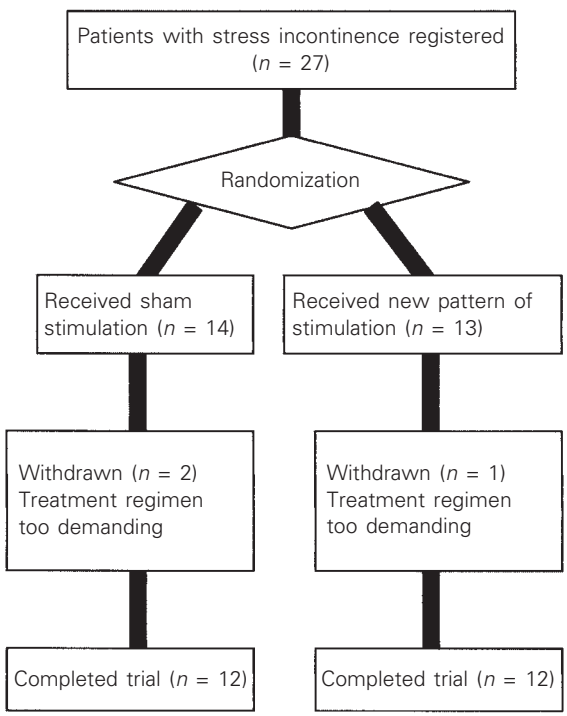

Figure 1 Flow of patients through the study.

Patients were required to keep a stimulation diary and compliance ranged from 64% to 100% for the sham group, and 71% to 98% for the treatment group.

The data obtained pre- and post-treatment outcome measures are presented in Figures 2–4 (data pertaining to the frequency/volume charts have not been presented due to incomplete data).

A summary of the actual and percentage changes is presented in Table 2. No statistically significant between- or within-group differences were highlighted when strength was measured using perineometry ($p = 0.86$). In contrast, when strength was assessed using digital assessment a statistically significant difference over time was found within both sham and stimulation groups ($p = 0.01$ for both groups). When endurance was assessed with perineometry, a percentage reduction (–6% ± 24%) was observed in the sham group, whilst the stimulation group improved (73% ± 116%). However, no statistically significant between-group difference was identified and this may have been the result of the high degree of variance combined with a small sample size.

With regard to symptoms and overall quality of life, no improvements in symptoms or quality of life were observed when assessed with the pad test and frequency/volume charts and IIQ, respectively. With the UDI score, however, a sig-

Table 1 Results of between-groups comparisons of baseline data using the independent samples *t*-test and the Mann–Whitney *U*-test

Variable	Sham	Stimulation
Baseline data for parametric variables (mean ± SD)		
Pelvic floor muscle strength (PM)	18.67 ± 7.44	20.09 ± 16.11
Pelvic floor muscle endurance (PM)	21.57 ± 5.13	23.58 ± 20.17
Incontinence Impact Questionnaire (IIQ)	39.22 ± 18.38	32.55 ± 18.02
Urogenital Distress Inventory (UDI)	41.58 ±15.44	46.27 ± 16.27
Baseline data for nonparametric variables (median and range)		
Pelvic floor muscle strength (DA)	8.5 (7–13)	8 (1–12)
Pad weight gain (g)	4.6 (0–43)	11 (0–35.4)
Leaks per week	2 (0–8)	4.5 (0–9)

PM, perineometry (cmH_2O); DA, digital assessment (scale: 0–15).
IIQ and UDI have the same scoring system (0–100).

nificant between-group difference was highlighted ($p = 0.01$). On further analysis a significant ($p = 0.03$) reduction in UDI scores was identified in the group receiving stimulation but not in the placebo group, thus indicating an improvement in quality of life for the treatment group.

Discussion

Although no significant between-group changes in strength and endurance were observed, there was a significant improvement within the stimulation group when strength was measured using digital assessment. However, these changes in muscle were not accompanied by a reduction in symptoms as measured by the one-hour pad test. Possible reasons for this are:

1) This is a true physiological effect and increased strength and endurance does not have any effect on incontinence or may possibly make it worse.

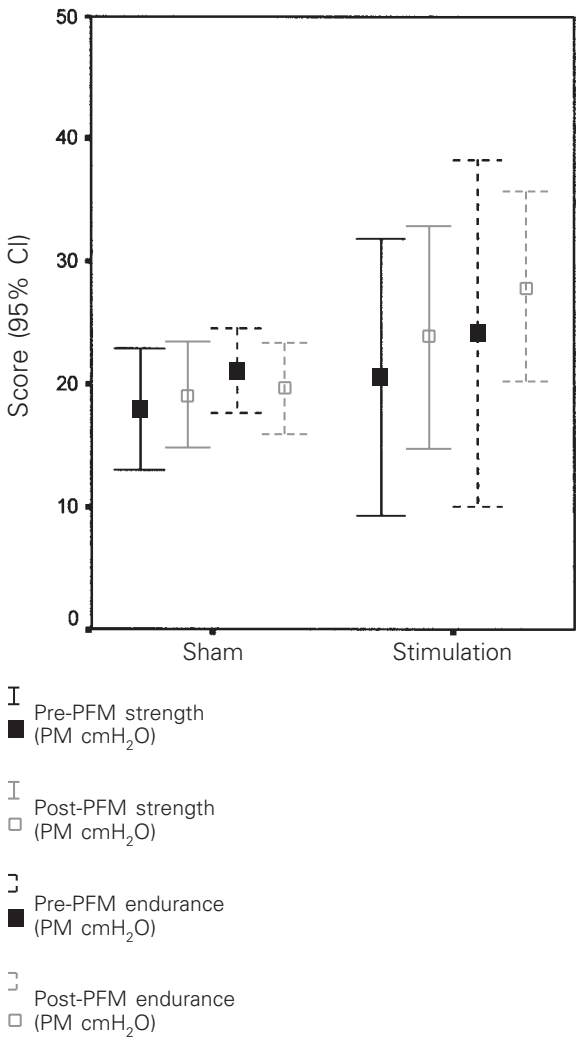

Figure 2 Changes in pelvic floor muscle (PFM) strength and endurance as measured using perineometry

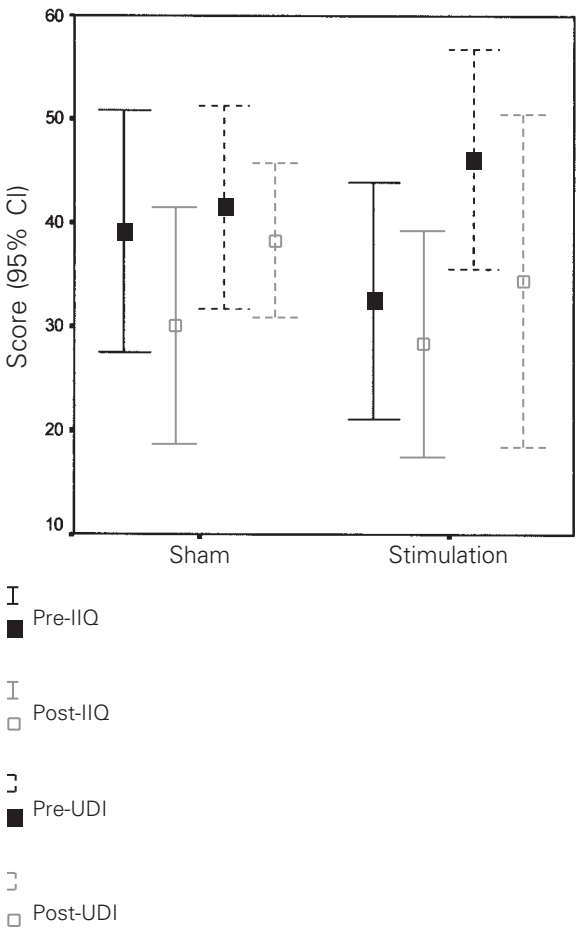

Figure 3 Changes in quality of life as measured using the Incontinence Impact Questionnaire (IIQ) and Urogenital Distress Inventory (UDI)

Clinical messages

- Patterned electrical stimulation may increase strength and endurance of muscle.
- Using patterned electrical stimulation did not improve pelvic floor muscle function.
- However, it may have reduced patient distress.

2) The pad test adopted was not sensitive enough to detect a change in severity of incontinence[23–25] or had poor compliance, whilst the frequency/volume chart had extremely poor compliance (only half the sample returned both pre and post frequency/volume charts). This last problem was not highlighted by the initial review that was conducted to determine the most suitable duration for a frequency/volume chart[26] (although more recent studies have reported similar findings[27]).
3) Individual patient variability in response masked the true effect highlighted by the large standard deviations that were observed. This was also observed with the other outcome measures.
4) As a result of the short stimulation time, it is possible that the changes in endurance and strength were only due to changes in blood supply and enzyme profile, as opposed to actual changes in the muscle contractile machinery. This may explain why these changes did not manifest themselves as a reduction in symptoms.

It is not possible to determine from this study which of these four explanations contributed to the observed results. The large variability in results (see Table 2) did however, have a profound influence on the results. Indeed a recalculation of number of subjects required on the basis of results from this study would indicate the need for 93 subjects in each group to show a statistically significant difference at the 5% level. The large SD in response was not predicted on the basis of previous investigations. Furthermore, the reduction in pad weight required for statistical significance (30 g), as described in the power calculation may have been unrealistic when using electrical stimulation alone to treat patients with stress incontinence. Possible reasons for the changes observed are discussed below.

Changes in strength and endurance

With regard to the changes in pelvic floor muscle strength, it would appear from the results that the new stimulation pattern demonstrated trends towards a significant improvement when measured using digital assessment. The new stimula-

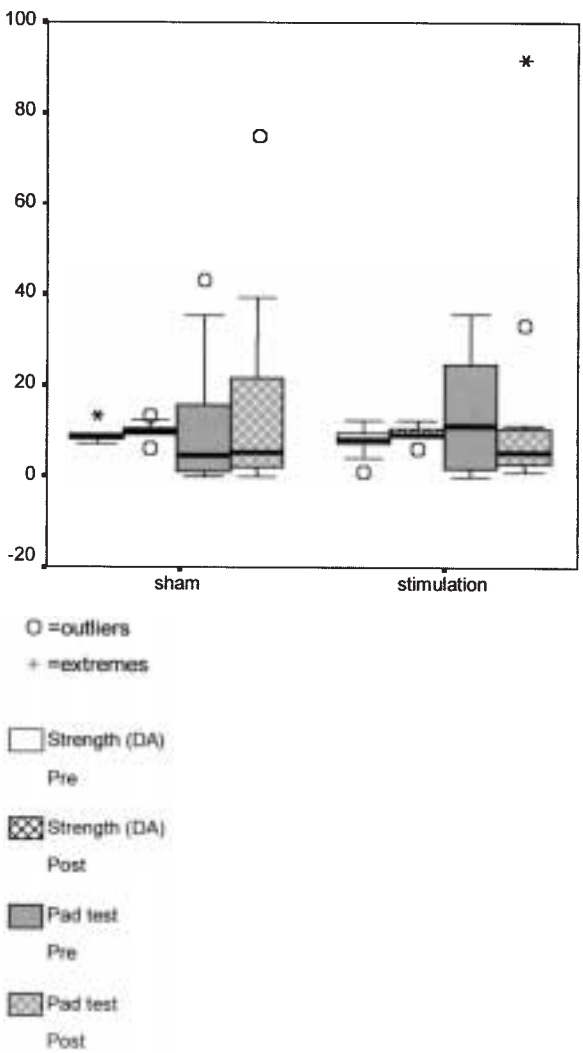

Figure 4 Changes in pelvic floor muscle strength (measured using digital assessment) and severity of incontinence (measured with the 1-hour pad test).

Table 2 Changes in the various outcome measures for both sham and stimulation groups when comparing pre- and post-stimulation results

Variable	Sham		Stimulation	
	Change	% Change	Change	% Change
Parametric variables (mean ± SD)				
Pelvic floor muscle strength (PM)	1.0 ± 5.3	25 ± 66	3.1 ± 12.5	88 ± 206
Pelvic floor muscle endurance (PM)	–2.0 ± 5.3	–6 ± 24	4.8 ± 13.9	73 ±113
Incontinence Impact Questionnaire (IIQ)	–9.1 ± 17.1	–11 ± 57	–4.1 ± 16.4	–0.3 ± 64
Urogenital Distress Inventory (UDI)	–3.3 ± 8.3	9 ± 62	–11.8 ± 15.9*	–31 ± 40
Nonparametric variables (median and range)				
Pelvic floor muscle strength (DA)	1 (–2 to +4)	11 (0 to +22)	1 (–1 to +5) **	12(0 to +35)
Pad weight gain (g)	0.1 (–15 to +61)	–16 (–100 to +436)	0.5 (–33 to +71)	0 (–93 to +500)
Leaks per week	–2 (–4 to 0)	–59 (–100 to –29)	0 (–5 to +4)	–60 (–100 to +133)

Statistical values indicate within-group comparisons.
$^{*}p < 0.05$; $^{**}p < 0.01$.
PM, perineometry (cmH_2O); DA, digital assessment (scale: 0–15).
IIQ and UDI have same scoring system (0–100).

tion pattern contained three components: a doublet, a high-frequency burst and a background low frequency. As the latter component was unlikely to target strength-generating characteristics, the significant increase in strength observed with digital assessment in the intervention group was likely to be the result of the intermittent high frequency (50 Hz) and the doublet component within the pattern. Other studies have also shown that high frequency stimulation can increase the strength of muscle.[28,29] Furthermore, the reaction of fast twitch fibres to doublet discharges[30] and the doublet discharges themselves can increase strength still further.[31,32]

It has been reported previously that patterns of electrical muscle stimulation containing a high-frequency component result in a decrease in the endurance characteristics of a muscle.[33] This was not observed in this study, indeed an increase in endurance characteristics was seen. It can be hypothesized, therefore, that the high-frequency component of the stimulation pattern did not have any significant detrimental effects, as are usually observed. Furthermore, there is also now evidence that high-frequency components only target stimulated fast fibres, whilst lower frequency components of the pattern targeted the fibres with a slower contraction time.[34]

The preservation of endurance characteristics with this new pattern of stimulation containing high-frequency components may also have been due in part to the efforts taken to reduce over-stimulation and thus prevent premature fatigue. With the new pattern the number of impulses was kept to a minimum and adequate rest periods were incorporated between trains. This desire to prevent over-fatigue may, however, have reduced the opportunity for optimal change within the muscle.

The changes observed in other studies, especially those involving animal models incorporated stimulation periods far longer than those in this study. The transformations, which occur as a result of chronic low frequency stimulation, adopt the following time course: initially there is a change in proteins of the sarcoplasmic reticulum.[35]. After two weeks of stimulation changes in enzymatic profile occur,[36] there is an elaboration of capillary networks within the muscle[37] and a reduction in oxygen diffusion distances.[38] Changes in heavy and light chains of myosin are initiated after 3–4 weeks of stimulation and only reach completion after between 12 and 20 weeks of stimulation.[33,34] As the stimulation time in this present study was only eight weeks and for 1 hour per day rather than continuous, these latter stages of adaptation stages are unlikely to have been completed.

Changes in severity of incontinence

In this study pad weight gain increased, but the number of leaks per week decreased. Both parameters would be expected to improve, i.e. decrease as a result the changes observed in pelvic floor muscle strength and endurance. Possible explanations have been put forward earlier in this discussion. However, it should be noted that although the one-hour pad test allowed standardization due to the use of a pre-defined protocol, this may have been at the expense of sensitivity.[22–24] A recent study[25] reported that although reliable, the ICS-recommended one-hour pad test underestimated patients' incontinence. However, in this study the opposite was found. One patient reported an improvement in symptoms as measured using the Urogenital Distress Inventory, but this was accompanied with an increase in pad weight, due to the patient suffering from a cold on the final assessment, but not on the baseline assessment. For similar studies a more appropriate pad test may be a 24- or 48-hour home pad test.

With regard to the SF-36 scores there were no significant between-group differences and as a result of its generic nature some patients stated that they completed the questionnaire with other problems such as moving house or back pain in mind. This highlights the insensitivity of a generic quality of life measure for use with a population with incontinence. However, this evidence was anecdotal, so there was no way of determining what the true impact was on these results.

There was no significant difference between groups when quality of life was measured with the IIQ, however with the UDI a significant between-group difference was highlighted. This may be due to the fact that these questionnaires address different aspects of the effects of incontinence. The IIQ is concerned with the degree to which the urinary incontinence affects daily activ-

ities such as shopping as well as various feelings such as frustration.[20,39] The UDI is more concerned with the degree to which the symptoms associated with lower urinary tract dysfunction bother women.[20,39] Therefore, results would suggest that although patients experienced a decrease in symptoms, this did not affect their emotional well-being or daily activities. This could be because the reduction in symptoms was not large enough to have a significant impact on the patients' quality of life.

Conclusion

In summary, trends towards improvements in strength and endurance were observed, although these changes were not translated into a reduction in symptoms in all patients. This may have been due to a number of reasons such as the treatment time being too short or the electrical stimulation needing to be combined with functional exercise to optimize the effects. Other limitations of the study, which may have resulted in the lack of statistical significance, are the large degree of variance that had implications on sample size considerations, the reduced sensitivity of some of the outcome measures and compliance.

Possible areas for further research would be to investigate the effects of the new stimulation when combined with pelvic floor exercises and to compare the new pattern of stimulation with existing forms of electrical stimulation.

Acknowledgements

Funding for this project was provided by University of Manchester Medical Bequest Fund. We would also like to thank Chris Chapman and Jill Bolderson for their help with this study.

References

1 Brocklehurst JC. Urinary incontinence in the community – analysis of a MORI poll. *BMJ* 1993; **306**: 832–34.
2 Agency for Health Care Policy and Research (AHCPR). Clinical practice guideline update. *Urinary incontinence in adults: acute and chronic management*. Maryland: Department of Health and Human Services, Public Health Service, 1996.
3 Royal College of Physicians. *Incontinence: causes, management and provision of services*. London: Royal College of Physicians, 1995.
4 Roe BH. A comparison of nursing approaches for the promotion and management of continence in the UK and Denmark. *Int J Nurs Stud* 1993; **30**: 25–35.
5 Yarnell JG, Voyle GJ, Richards CJ, Stephenson TP. The prevalence and severity of incontinence in women. *J Epidemiol Commun Health* 1981; **35**: 71–74.
6 Mantle J, Versi E. Physiotherapy for stress urinary incontinence: a national survey. *BMJ* 1991; **302**: 753–55.
7 Kidd G, Oldham J. An electrotherapy based on the natural sequence of motor unit action potentials: a laboratory trial. *Clin Rehabil* 1988; **2**: 125–38.
8 Kidd G, Oldham JA. Motor unit action potentials (MUAP) sequence and electrotherapy. *Clin Rehabil* 1988; **2**: 23–33.
9 Jarvis JC. Power production and working capacity of rabbit tibialis anterior muscles after chronic electrical stimulation at 10 Hz. *J Physiol* 1993; **470**: 157–69.
10 Mayne CN, Sutherland H, Jarvis JC, Gilroy SJ, Craven AJ, Salmons S. Induction of a fast-oxidative phenotype by chronic muscle stimulation: histochemical and metabolic studies. *Am J Physiol (Cell Physiol)* 1996; **270**(suppl 39): C313–C320.
11 Jarvis JC, Sutherland H, Mayne CN, Gilroy SJ, Salmons S. Induction of fast-oxidative phenotype by chronic muscle stimulation: mechanical and biochemical studies. *Am J Physiol (Cell Physiol)* 1996; **270**(suppl 39): C306–C312.
12 Karu ZZ, Durfee WK, Barzilai AM. Reducing muscle fatigue in FES applications by stimulating with N-let pulse trains. *IEEE Trans Biomed Eng* 1995; **42**: 809–17.
13 Kwende MMN, Jarvis JC, Salmons S. The input–output relations of skeletal muscle. *Proc R Soc Lond B Biol Sci* 1995; **261**: 193–201.
14 Sand PK, Richardson DA, Staskin DR, Appell RA, Whitmore KE, Ostergard DR. Pelvic floor electrical stimulation in the treatment of genuine stress incontinence: a multicentre placebo-controlled trial. *Am Obstet Gynecol* 1995; **173**: 72–79.
15 Laycock, J. Does pre-modulated interferential therapy cure stress incontinence? *Physiotherapy* 1993; **79**: 553–60.
16 Abrams P, Blaivas JG, Stanton SL, Andersen JT. The standardisation of terminology of lower urinary tract function. *Scand J Urol Nephrol Suppl* 1988; **114**: 5–19.
17 Wyman JF, Choi SC, Harkins SW, Wilson MS, Fantl JA. The urinary diary in evaluation of incontinent women: a test-retest analysis. *Obstet Gynecol* 1988; **71**: 812–17.
18 Roe B, Wilson K, Doll H, Brookes P. An evaluation of health interventions by primary health care teams and continence advisory services on patient

outcomes related to incontinence. Health Services Research Unit, Department of Public Health and Primary Care, University of Oxford, Oxford, 1996.
19 Uebersax JS, Wyman JF, Shumaker SA, McClish D, Fantl JA. Short forms to assess life quality and symptom distress for urinary incontinence in women: the incontinence impact questionnaire and the urogenital distress inventory. *Neurourol Urodyn* 1994; **14**: 131–39.
20 Shumaker SA, Wyman JF, Uebersax JS, McClish D, Fantl JA. Health-related quality of life measures for women with urinary incontinence: the incontinence impact questionnaire and the urogenital distress inventory. *Qual Life Res* 1994; **3**: 291–306.
21 Oldham J. International Patent Publication WO97/47357, 1997.
22 Armstrong C. Development of an optimised electrical stimulation regime for strengthening the hand muscles. PhD thesis, University of Manchester, 1998.
23 Mouritsen L, Berild G, Hertz J. Comparison of different methods for quantification of urinary leakage in incontinent women. *Neurourol Urodyn* 1989; **8**: 579–87.
24 Klarskov P, Hald T. Reproducibility and reliability of urinary incontinence assessment with a 60min test. *Scand J Urol Nephrol* 1984; **18**: 293–98.
25 Devreese AM, De Weerdt WJ, Feys HM *et al.* Functional assessment of urinary incontinence: the perineal pad test. *Clin Rehabil* 1996; **10**: 210–15.
26 Jeyaseelan SM. A pilot evaluation of a new pattern of electrical stimulation as a treatment for genuine stress incontinence: a randomised, double-blind, controlled trial. PhD thesis, University of Manchester, 1999.
27 Brubaker L, Benson JT, Bent AE, Clark A, Shott S. Transvaginal electrical stimulation for female urinary incontinence. *Am J Obstet Gynecol* 1997; **177**: 536–40.
28 Delitto A, Rose SJ, McKowen JM, Lehman J, Thomas JA, Shively RA. Electrical stimulation versus voluntary exercise in strengthening thigh musculature after anterior cruciate ligament surgery. *Phys Ther* 1988; **68**: 660–63.
29 Selkowitz DM. Improvement in isometric strength of the quadriceps femoris muscle after training with electrical stimulation. *Phys Ther* 1985; **65**: 186–96.
30 Kress M, Huxley HE, Faruqui AR, Hendrix J. Structural changes during activation of frog muscle studied by time resolved X-ray diffraction. *J Mol Biol* 1986; **188**: 325–42.
31 Pette D. Early effects of chronic low frequency on calcium sequestering proteins and contractile properties of rabbit fast-twitch muscle. In: Pette D, Rose F, Jones R, Vrbova G eds. *Neuromuscular stimulation: basic concepts and clinical application*. New York: Demos, 1989.
32 Sweeney H, Bowman B, Stull J. Myosin light chain phosphorylation in vertebrate striated muscle: regulation and function. *Am J Physiol (Cell Physiol)* 1993; **264**: C1085–C1095.
33 Nix W, Vrbova G eds. *Electrical stimulation and neuromuscular disorders*. Berlin: Springer-Verlag, 1986.
34 Belanger AY. Neuromuscular electrostimulation in physiotherapy: a critical appraisal in controversial issues. *Physiother Theory Pract* 1991; **7**: 83–89.
35 Pette D, Heilmann C. *Basic Res Cardiol* 1977; **72**: 247–53.
36 Pette D, Smith M, Staudte H, Vrbova G. Effects of long term electrical stimulation on some contractile and metabolic characteristics of fast rabbit muscles. *Pflugers Arch* 1973; **338**: 257–72.
37 Hudlicka O, Myrhage R. *J Physiol* 1976; **258**: 25P–6P.
38 Pette D, Muller W, Leisner E, Vrbova G. Time dependent effects on contractile properties, fibre populations, myosin light chains and enzymes of energy metabolism in intermittently and continuously stimulated fast-twitch muscles of the rabbit. *Pflugers Arch* 1976; **364**: 103–12.
39 Salmons S, Sreter FA. Significance of impulse activity in the transformation of skeletal muscle type. *Nature* 1976; **263**: 31–35.
40 Valerius AJ. The psychological impact of urinary incontinence on women aged 25 to 45 years. *Urol Nurs* 1997; **17**: 96–103.