Pressure Changes Under The Ischial Tuberosities Of Seated Individuals During Sacral Nerve Root Stimulation

Liu LQ [1], Craggs MD [1], Nicholson GP [2], Knight SL [1], Chelvarajah R [1], Bycroft J [1], Middleton FRI [3], Ferguson-Pell M [2]

[1] Spinal Research Centre, RNOH & Institute of Urology, University College London
[2] CDRI, RNOH
[3] Spinal Injury Unit, RNOH

Email: l.liu@ucl.ac.uk

Abstract

The ischial tuberosities (IT) are the most vulnerable sites for debilitating pressure ulcers (PU) in SCI patients. Interestingly, functional electrical stimulation (FES) over the gluteal muscles can vary the buttock tissue shape, redistribute seating pressure and reduce interface pressure in the IT region. Non-invasive Functional Magnetic Stimulation (FMS) of the S2 sacral nerve roots can also reliably activate gluteal muscles. The aim of this study was to 1) investigate the acute effects of sacral FMS on seating interface pressure changes in healthy volunteers and demonstrate its utility as an assessment tool and 2) show that similar effects are possible with FES in SCI using a SARSI implant. With stimulation, average IT peak pressures reduced significantly in both healthy controls (~20%) and SCI patient (~40%). This study has demonstrated for the first time that S2 nerve root stimulation by FMS or implanted FES can induce gluteal muscle contractions sufficient to achieve significant ischial pressure reduction. In addition to these beneficial acute effects, chronic stimulation via a SARS implant may also be useful for building gluteal muscle bulk as a further important preventative measure to reduce PU in SCI patients.

1 Introduction

Pressure ulcers in the gluteal region constitute one of the most serious complications in the wheelchair based spinal cord injured population [1]. It affects up to 56% of this group of patients [2]. Prolonged localized pressure loaded on wasted gluteal muscles coupled with insensitivity to ischemia below the level of the lesion have long been considered to be the most important factor [3][4]. At present, specialised cushions to reduce interface pressures combined with pressure relief by the patient performing 'push-ups' or 'leaning forward' is the best option for preventing PU in spinally injured patients. Performing pressure relief requires sufficient upper limb strength, which may not present in a high level lesion, and continued motivation. Surface functional electrical stimulation (FES) of gluteus maximus has been reported to change the shape of loaded buttocks and reduce interface pressure in gluteal region [5][6], however the muscles have to be stimulated in a cumbersome manner by repeatedly sticking large electrode pads on the skin. The long-term practicality and patient compliance with this technique is a problem. However, an implanted FES device may be a more practical solution especially if its utility can be demonstrated non-invasively beforehand. For this purpose non-invasive functional magnetic stimulation (FMS) of the sacral nerve roots can achieve gluteal and pelvic floor muscles contraction in an effective and non-invasive manner [7]. Additionally, for chronic stimulation of gluteal muscles, electrical stimulation through implanted electrodes may be a more effective alterative to build muscle bulk and reduce seating pressure, thus prevent ischial pressure ulcers in the wheelchair bound spinal cord injured population.

The aim of this study was to 1) investigate the acute effects of sacral FMS on seating interface pressure changes in healthy volunteers and demonstrate its utility as an assessment tool and 2) show that similar effects are possible with FES in SCI using a Finetech-Brindley SARS implant.

2 Methods

2.1 Subjects

Local ethical approval and informed consent was obtained; 5 able-bodied male subjects and 1 female SCI patient (T7/T8 complete) with a SARS implant were recruited for this study.

2.2 Functional Magnetic Stimulation (FMS)

FMS was delivered using a Medtronic Dantec MagPro with a large circular coil. Stimulation frequencies in the range of 15-25pps at 50-70% intensity for 2 seconds were utilised.

The optimal coil position for sacral nerve root stimulation was determined by mapping the gluteal muscle response [7]. The coil was placed over various points of a grid pattern ranging from the line of the iliac crest to 10 cm below and 8 cm either side of midline.

2.3 Stimulation via SARSI implant

Electrical stimulation was applied bilaterally via implanted Finetech-Brindley Sacral Anterior Root Stimulator Implant (SARSI). The S2 nerve root was stimulated using a frequency of 20pps and amplitude '1', the pulse width was varied from 8-800μs

2.4 Ischial pressure measurement

Each subject sat in a wheelchair with standard cushion (high resilience foam, density 45kg/m^3). Ischial pressures were measured using interface pressure map (Xsensor Technology Corporation 36×36 cells at 10mm; Calgary, Alberta, Canada). Seating pressures were recorded before, during and after stimulations.

2.5 Phantom Study

To identify possible interference of magnetic stimulation on interface pressure map acquisition hardware**,** we carried out a phantom study, previous studies have reported artefacts due to magnetic stimulation**.** We applied magnetic stimulation in gel buttocks to measure the effects of the magnetic pulses on the interface pressure mapping system. Magnetic stimulating coil was applied against the 'sacrum area' of gel buttocks and energized at single pulse and frequencies of 5-20Hz and intensity of 30% to 90% of maximum expected stimulator output during mapping interface pressure at 10% intervals. We compared the results of interface pressure measurements made with the stimulator off and on in gel buttocks and detected no effect of magnetic stimulation on the results of pressure values.

3 Results

3.1 Results from able-bodied subjects

All able-bodied subjects tolerated FMS well. Figure 1 shows typical interface pressure distribution before and during stimulation in one subject; Figure 2 shows bilateral IT peak pressure traces before, during and after stimulation, where the coil was placed at midline of S2 level. The difference between resting and stimulated pressures at the ischial was statistically significant in both sides of all subjects.

For the group (n=5), the average peak pressure drop was 20.3±7.5mmHg; IT peak pressures decreased during FMS as compared to baseline (127.5.0 ± 17mmHg vs. 107.7 ± 18mmHg, $p<0.0001$) (Figure3). The optimal response was achieved with the coil located at S2 level (about 6cm below iliac crest). For bilateral stimulation the optimal coil position was midline, and for unilateral stimulation the optimal position was at 2-4cm lateral to midline. Increased intensity of FMS was associated with a greater reduction in peak interface pressure

3.2 Results from SARSI patient

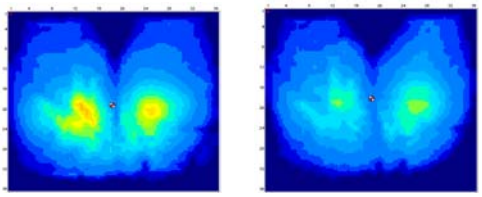
Bilateral S2 stimulation caused a palpable contraction of the gluteus maximus and associated hip and leg movement. Peak pressures under ischial tuberosities were significantly decreased (109.5 ± 5.6 mmHg at resting vs 64.07 ± 4.6 mmHg during stimulation, $p<0.0001$) (Figure4). Maximum reduction of IT peak pressure was obtained at a stimulation pulse width of 256 μs, frequency of 20 pps .

4 Discussion and Conclusions

Our preliminary results indicated that reduction of ischial pressures during sitting could be achieved by sacral nerve root stimulation, either by using FMS or implanted sacral nerve stimulator. In the able-bodied subjects, maximal effects were obtained approximately over S2 by using magnetic stimulation; in 1 SCI patient with SARSI implant, maximum reduction of IT peak pressure was obtained when stimulating S2 with pulse width of 256 μs, frequency of 20 pps.

Sacral Functional Magnetic Stimulation or through an implanted stimulator effectively induced gluteal muscle contraction and pelvic tilt, which significantly reduced the seating pressures. The magnitude of peak pressure reductions in this study were similar to those obtained by Ferguson *et al* [8] with electrical stimulation of quadriceps but greater than those produced by Levine [7] with stimulation of gluteal muscles. In our study, IT peak pressure produced a 42% reduction in 1 SCI patient and nearly 20% reduction in 5 able-bodied subjects. This difference between healthy males and a

single female SCI patient may simply reflect the variation of individual's body weight, differences in pelvic anatomy or small sample sizes. More likely it is the potential for greater benefit in patients already suffering from muscle wasting of the buttocks.



(a) *(b)*

Figure 1: *Seating pressure distribution in one able-bodied male subject (a) before and (b) during functional magnetic stimulation of the S2 roots.*

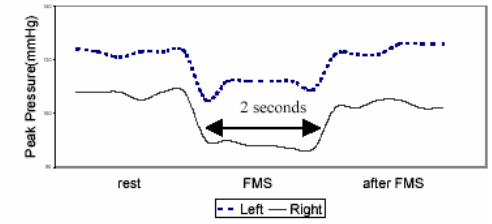


Figure 2: *Bilateral peak pressure at rest, during and after FMS when coil placed optimally in the midline over the sacral S2 level of the subject shown in Figure 1 above.*

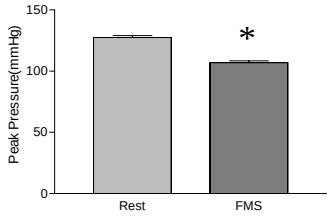


Figure 3: *Peak pressures before and during optimal stimulation in 5 able-bodied male subjects. Values are expressed as mean ±SD. * p<0.0001.*

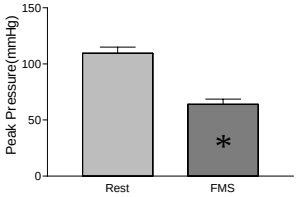


Figure 4: *Peak pressures before and during optimal S2 electrical stimulation through a Finetech-Brindley SARS in one patient.Values expressed as mean ± SD.*
** p<0.0001.*

While the formation of a pressure ulcer is undoubtedly a multifactorial event, the application of a prolonged pressure loading to exceed the tissue tolerance is the main factor that allows ulcers to develop. Therefore, a sensible approach of preventing ischial pressure ulcers is to redistribute seating interface pressure and reduce pressures under ischial tuberosity by regular stimulation of S2 sacral nerve roots to achieve gluteal muscle contraction and increase muscle bulk.

There is a further important issue concerning tissue perfusion now being studied in our Centre. Although the pressure changes recorded in this study were statistically significant, the application in a clinical setting is a more complex issue. Ischial blood perfusion during the stimulation is presently under investigation by using Tissue Reflectance Spectrometer and Laser Doppler Flowmetry. Gluteal muscle thickness after chronic stimulation is also measured by ultrasound image. If the pressure reductions can improve local vascular circulation, an implanted S2 sacral nerve roots stimulator (SARSI currently used for bladder emptying) may form the basis of an alternative method of ischial pressure ulcer prevention. We expect to present these results when ready to a future meeting of the Society.

References

[1] Bryne DW, Salzberg CA. Major risk factors for pressure ulcers in the spinal cord disabled: a literature review. *Paraplegia* 34: 255-263; 1996.

[2] Ash D. An exploration of the occurrence of pressure ulcers in a British spinal injuries unit. *J Clin Nurs Jul*;11(4):470-8; 2002.

[3] V. Schubert, B. Fagrell Postocclusive reactive hyperemia and thermal response in the skin microcirculation of subjects with spinal cord injury. *Scand J Rehab Med* 23:33-40,1991.

[4] Mawson, A *et al* Sacral Transcutaneous Oxygen Tension Levels in the Spinal Cord Injures: Risk factors for Pressure Ulcers? 74;745-51; 1993.

[5] Levine SP, Kett RL, Cederna PS, Brooks SV. Electric muscle stimulation for pressure soreprevention: tissue shape variation. *Arch Phys Med Rehabil.* 1990 Mar;71(3):210-5.

[6] Levine SP, Kett RL, Cederna PS, Bowers LD, Brooks SV. Electrical muscle stimulation for pressure variation at the seating interface. *J Rehabil Res Dev. Fall*;26(4):1-8; 1989.

[7] Sheriff, M.K.M, Shah, P.J.R, Fowler, C, Mundy, A.R, Craggs, M.D Neuromodulation of detrusor hyper-relexia by functional Magnetic Stimulation of sacral roots *British Journal of Urology* ,78,39-46, 1996.

[8] Ferguson AC, Keating JF, Delargy MA, Andrews BJ. Reduction of seating pressure using FES in patients with spinal cord injury. A preliminary report. *Paraplegia*. Jul;30(7):474-8; 1992.

Acknowledgements

This work is funded by the Royal National Orthopaedic Hospital and also supported by ASPIRE.