RESEARCH

Action Potential Simulation Therapy: Self Assessment by 285 patients with chronic pain

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It is believed that A-beta fibres (low threshold mechanoreceptors from the skin) give off colaterals as they pass upwards in the spinal cord, which impinge on the nociceptor cells of the A-delta and C-pain fibres, effectively reducing the excitability of these nociceptor cells. Thus, electrical impulses which stimulate these A-beta fibres are effective in reducing pain perception. Electrotherapy has therefore been used as a treatment modality for pain and swelling.

Dit word voorgestel dat A-beta vesels (lae drempel meganoreseptore vanaf die vel) kolateraal versprei soos wat dit deur die rugmurg opwaarts beweeg en inbreuk maak op die nosiseptorselle van die A-delta en C-pyn vesels,en sodoende die eksiteerbaarheid van die nosiseptorselle verlaag. Elektriese impulse wat die A-beta vesels stimuleer verminder pynwaarneming effektief en word dus as behandelingsmetode vir pyn en swelling gebruik.

In hierdie studie is pynverligting gemeet deur gebruik te maak van 'n visuele pyn analoog skaal (VPAS) en mobilitieitsindeks (MI) in 285 pasiënte met 'n verskeidenheid van kliniese diagnoses met betrekking tot pyn. Pasiënte is evalueer vir basislyn op dag een en dan op dag vyf na vyf dae van behandeling met elektroterapie (Aksiepotensiaal Simulasie, APS). Die gemiddelde VPAS en MI het betekenisvol verbeter in die groep as totaal sowel as in groepe wat verdeel is in onder 50 jaar oud en ouer as 50 jaar. Op kliniese gronde en deur pasiënte selfevaluering was APS terapie suksesvol. APS gebruik perifere senuwee stimulasie om pyn te verlig. Daar word gebruik gemaak van die vinniger A-beta vesels wat stimulasie van die C-vesels belemmer (nosiseptore) en dus pyn waarneming blokkeer. Die rol van opoïede moet ook nie onderskat word nie. Verdere navorsing is nodig om die positiewe effekte van ekeltroterapie op die gesondheid van persone te verklaar.

In this study pain relief was assessed in 285 patients with varying clinical manifestations of pain, using the visual analog pain scale (VAPS) and mobility index (MI). Baseline measurements were taken on day one and then after five days of electrotherapy treatment (Action Potential Simulation, APS). The mean VAPS and MI improved significantly in the patient group as a whole, as well as in the two age-related groups, namely, below and above 50 years of age. Both on clinical grounds and by patient self assessment, APS therapy appeared to be most beneficial. This mode of treatment utilises peripheral nerve stimulation to relieve pain using the faster A-beta fibres which intercept stimulation from the C-fibres (nociceptors) and therefore, according to the gate theory, blocks pain perception. The role of opioids should also not be underestimated. Further research is warranted to fully understand the positive effects of electrotherapy on the health of the individual.

Nociception is defined as the neural response to noxious stimulation, pain as the conscious perception of nociception, and pain expression as the verbal coupled to behavioural signals that allow the clinician to assess the severity of the nociceptive stimulus[1]. The outward expression of pain is influenced by a variety of biopsychosocial factors including culture, mood and psychological state, and physical function. In addition, as the brain is actively involved in modulating and processing nociceptive stimuli, cognitive function is also likely to influence pain expression[2,3,4].

Excitable tissues, muscles and nerves, can be stimulated by suitable currents. This may lead to many

effects such as muscle contraction and modification of pain perception through the stimulation of the motor or sensory nerves. All sensations recognised at a conscious level, can be altered by the central nervous system. Chronic pain, which is recognised as slow pain, as opposed to acute pain (carried by small myelinated A-delta fibres and recognised as fast pain), is equated with tissue damage and is carried by small unmyelinated C-fibres[5].

The gate control theory suggested by Melzack and Wall in 1965, proposed that pain perception is regulated by a physiological "gate" which may be opened or closed, thus increasing or decreasing the pain perceived, by means of other inputs from peripheral nerves or from the central nervous system.[6] The A-beta fibres, low threshold mechanoreceptors from the skin, travel without synapsing, up the posterior columns of the spinal cord. These fibres give off collaterals, which impinge on the nociceptor cells of the A-delta and C-pain fibres in different laminae of the substantia gelatinosa of the spinal cord. It is believed that input from these mechanoreceptors effectively reduces the excitability of the nociceptor cells to pain-generated stimuli[7].

Thus electrical impulses which stimulate these A-beta mechanoreceptor fibres, are effective in reducing pain perception. "From the spinal region, transmission proceeds onward to supra-spinal levels, where pain perception is altered through the release of endogenous opioids." These and other substances are released at many other key regions in the brain and spinal cord, and through efferent discharge in local regions too.

Evidence has also shown that various forms of electrotherapy are capable of restoring normal cell membrane potential, thus affecting tissue growth and repair[8].

Opiates exert their action in the central nervous system by binding to specific receptors, and it has been discovered that there is an increased density of receptors in regions where electrical stimulation has an antinociceptive effect. An intense search for the natural ligand to these receptors led to the isolation of a number of endogenous opioid peptides, e.g., the encephalins and the endorphins. It has also been discovered that they exert an inhibitory modulation on the transmission of pain impulses. Furthermore, the electrical stimulation which leads to pain control and relief, sometimes correlated with the release of endogenous opioids.[9,10,11]

Electrotherapy is the use of electricity to cause a specific physiological response, and is a well-known and accepted treatment modality used by physiotherapists.[5] There are many different electrotherapy modalities available, each defined by different parameters such as frequency and intensity. Electrotherapy is considered to be an effective way of treating clinical conditions such as pain and swelling, by causing peripheral vasodilatation, which results in better perfusion of the affected areas.

The potential advantage of electrical stimulation as an adjunct to other pain therapies, is that this treatment modality is non-invasive and relatively safe. Such treatments have minimal side effects, assist in the reduction of medication and may improve the quality of life of the patient, permitting return to normal working and social activities.[12]

In 1992, a new electrotherapy modality was designed and brought onto the South African market - known as Action Potential Simulation (APS) Therapy. It was developed specifically for use in pain relief and pain control and for the improvement of mobility of stiff joints and muscles.[13] The device uses an electrical current that supposely mimics the normal physiological action potential of nerve conduction. This may be a unique concept to electro-physics. The device is said to produce action potentials that are four times stronger than those naturally occurring in the neuron.[8] When swelling, inflammation, poor circulation and pain occur due to mechanical, chemical or electrical disturbances, by stimulating the body's natural regenerative processes (as in depolarisation), these conditions are encouraged to resolve.

Various instruments have been designed for the actual measurement of the degree of pain; for example, the verbal rating scale, McGill pain questionnaire, pain drawings and descriptor pain perception profile, to name a few.[14,15] Each measuring instrument has its own degree of reliability and validity.[14] The word pain tends to be confusing. For some it is merely a pinprick, while for others it is an unbearable sensation. This makes it difficult to compare individuals' experiences of pain.[15,16] Thus the clinician, in order to evaluate the efficacy of pain intervention, due to lack of more substantive methods, must surely rely on self assessment of pain relief and control by patients. Use can be made of a pain intensity scale where each patient acts as its own control.

The aim of this study then was to allow self-assessment, before and after APS therapy of:

1. Pain relief
2. Improvement in mobility by patients with chronic pain and stiffness.

SUBJECTS AND METHODS

Approval for the study was obtained from the combined Ethics Committee of the University of Pretoria and the Gauteng Provincial Health Authorities.

Patients, who routinely attended two pain clinics for therapy, were used in this study. The total number of patients were 285. The clinical diagnosis varied considerably and was anatomically 'classified' as back, neck, knees, hands, hips, etc.

After a thorough physical examination, all patients were asked to fill in a visual analogue pain scale (VAPS) and mobility index (MI). Every patient gave a VAPS value for their specific pain condition. This value represented a combined impression of their pain for the previous week and was the baseline on which the whole study was built.

The VAPS consists of a 10cm horizontal line bounded by "no pain" on the left and "worst pain imagi-

TABLE I: THE DEMOGRAPHICS OF THE STUDY POPULATION

Total number of patients	285	Percentage
Male	161	56
Female	124	44
Mean age	50	
Male	42	
Female	60	
Oldest patient	94	
Youngest patient	9	
Medication		
Anti-inflammatory	48	17
Analgesics	4	1
No medication	233	82

nable" on the right end. Patients indicate their pain intensity on a 1-10 scale. The MI is a self-report and instrument to assess the degree to which chronic pain interferes with daily activities.[17,18] It has test-retest reliability and validity. As MI seems to be associated with levels of pain expression shown by patients,[17] VAPS and MI's were re-assessed in patients after five days of APS therapy. The average duration of treatment was 12 minutes with an intensity of between 1,1 and 1,3 mA.

TECHNICAL SPECIFICATIONS OF THE APS THERAPY DEVICE

Wave form:	Simulated Action Potential
Wave Type:	Monophasic Square Pulse with Exponential Decay
Amplitude:	Adjustable, 0-24.4 mA peak into 500 ohm load
Pulse rate:	150 Hz
Modulation:	Variable pulse width; automatic adjustment depending on distance between electrodes
Burst:	Continuous
Voltage:	0-46 Volts (open circuit)

RESULTS AND DISCUSSION

The demographics of our study population are shown in Table I. A relatively heterogeneous mixture of subjects - 56% male and 44% female with mean age of 42 for the males and 60 for the females. The mean age was 50. Our oldest patient was 94 and youngest 9. Seventeen percent of our subjects were taking anti-inflammatory drugs on a daily basis, while 1% were taking analgesics only on an 'as needed' (prn) basis. 234 subjects or 82% did not take any anti-inflammatories or analgesics.

The VAPS and MI before day 1 and after day 5 for all the patients as a whole are shown in table II. The mean VAPS and MI improved dramatically from 6,6 and 6,5 to 2,7 and 3,3 respectively.

The 'anatomical' classification of different injuries and conditions were as follows: The largest 2 groups (97 + 45) were classified as back and neck patients. These patients suffered mostly from back and neck pain due to spondilosis, disc degeneration with narrowing of the intervertebral disc spaces, paravertebral osteoarthritis, previous back surgery, spondilolisthesis, spondilolysis and N.ischiadicus root irritation, postural and mechanical (functional) back and neck ache. Clinical diagnosis in the other groups included osteoarthritis, rheumatoid arthritis, gouty arthritis, menisci lesions, ligamentous injuries, malalignment, flat feet, plantar fasciitis, rotator cuff syndrome, bad circulation, varicose veins, migraine, carpal tunnel syndrome, osteoarthritis jaw, tennis elbow, muscle spasms, etc. The effect before and after treatment on the VAPS and MI are depicted in Fig 1 and 2. In all groups, except for those with arms and jaw pain, the changes in VAPS were statistically significant ($P<0.001$). The small number of subjects (3) in the arms and jaw group may explain their non-significant results.

The patients were also divided in an above 50 years of age group and a below 50 years of age group, for both the VAPS and MI *(See Figures 3 & 4 on pg. 22)*. The average value as a whole for the VAPS for >50 years was 6,8 before treatment and 3,3 after treatment. In the <50 years age group, it was 6,3 and 2,2 respectively. Although both age groups improved dramatically there was a 15 % overall better response in the older age group.

The average value as a whole for the MI for >50 years was 6,7 before treatment and 3,4 after treatment. In the <50 years age groups it was 6,4 and 3,2 respectively. Both groups responded equally to treatment.

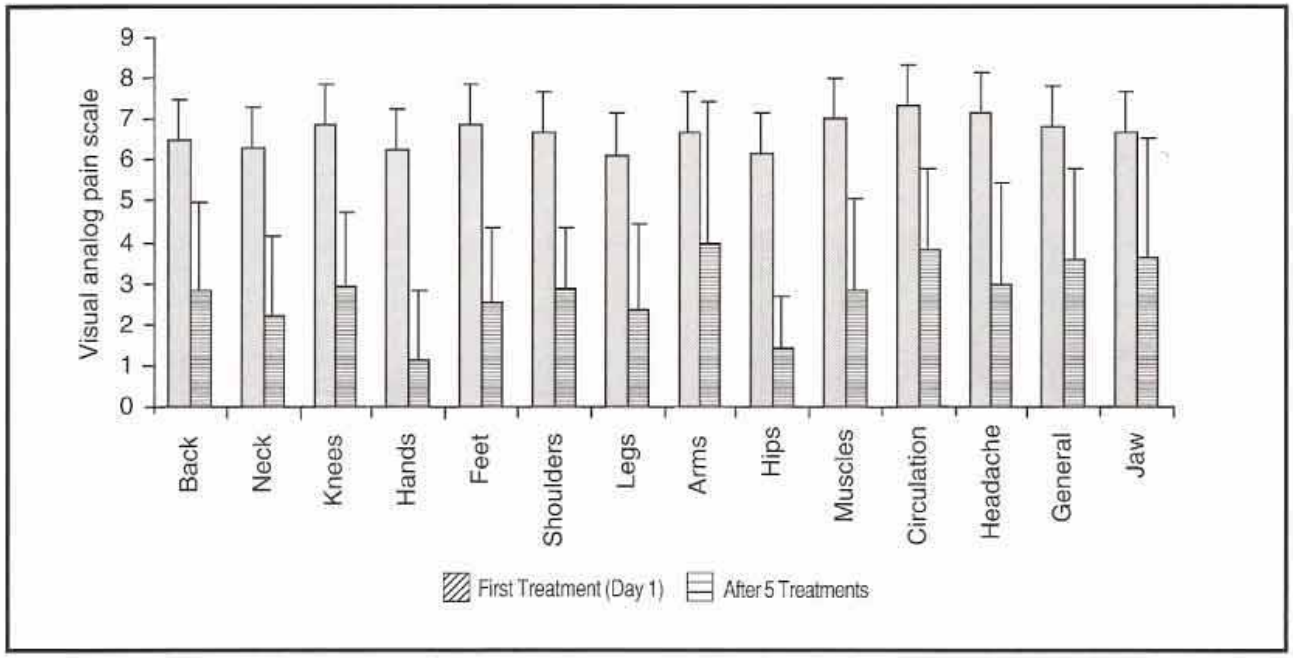
The best results were obtained in the elderly patients with neck

TABLE II: THE VISUAL ANALOGUE PAIN SCALE AND MOBILITY INDEX BEFORE AND AFTER TREATMENT

	Before Treatment		After 5 Treatments	
	Mean	**STDev**	**Mean**	**STDev**
VAPS (total)	6.6	1.4	2.7*	2
VAPS (male)	6.4	1.5	2.3*	2.1
VAPS (female)	6.8	1.1	3.3*	1.7
Mobility (total)	6.5	1.4	3.3*	1.8
Mobility (male)	6.4	1.5	3.2*	1.9
Mobility (female)	6.8	1.1	3.5*	1.7

*These changes are also depicted in fig 1 and II. *P < 0.001.*

FIGURE I: THE EFFECTS OF APS TREATMENT ON VAPS



problems. There was a 39 % and 25 % improvement in both their pain perception and mobility index.

Both clinically and on a subjective level, APS therapy appeared very successful. Out of the 285 patients, 44 (15%) ended with a '0' VAPS and 199 (69%) with a score of 5 or less. It is just as effective in younger as in older patients. All were extremely happy with the treatment and experienced both pain relief and pain control, with improved mobility in daily life. This study has also demonstrated significant clinical efficacy of the APS device. It was observed clinically that patients with severe osteoarthritic conditions and those who needed a total hip or knee replacement, responded less favourably when compared to people with less joint restriction and with only soft tissue injury. It is possible to speculate as to the physiological mechanisms involved. Measurement of endogenous opioid peptides, the encephalins and the endorphins, will hopefully be a more substantial future tool in the complex evaluation of pain.

APS utilises peripheral nerve stimulation to relieve pain by the myelinated afferent nerve fibres, which activate local inhibitory circuits within the dorsal horn of the spinal cord. These fibres (A beta) mediate inhibition largely segmentally[14]. These

FIGURE II: THE EFFECTS OF APS TREATMENT ON MOBILITY INDEX (MI)

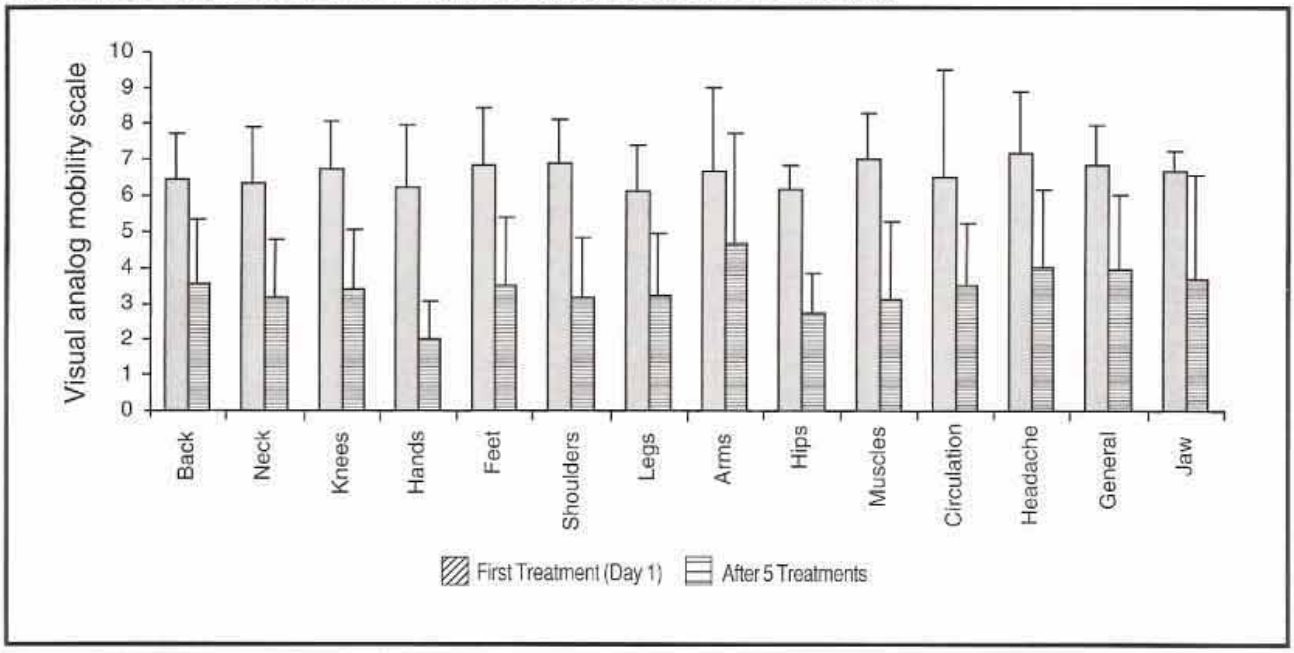
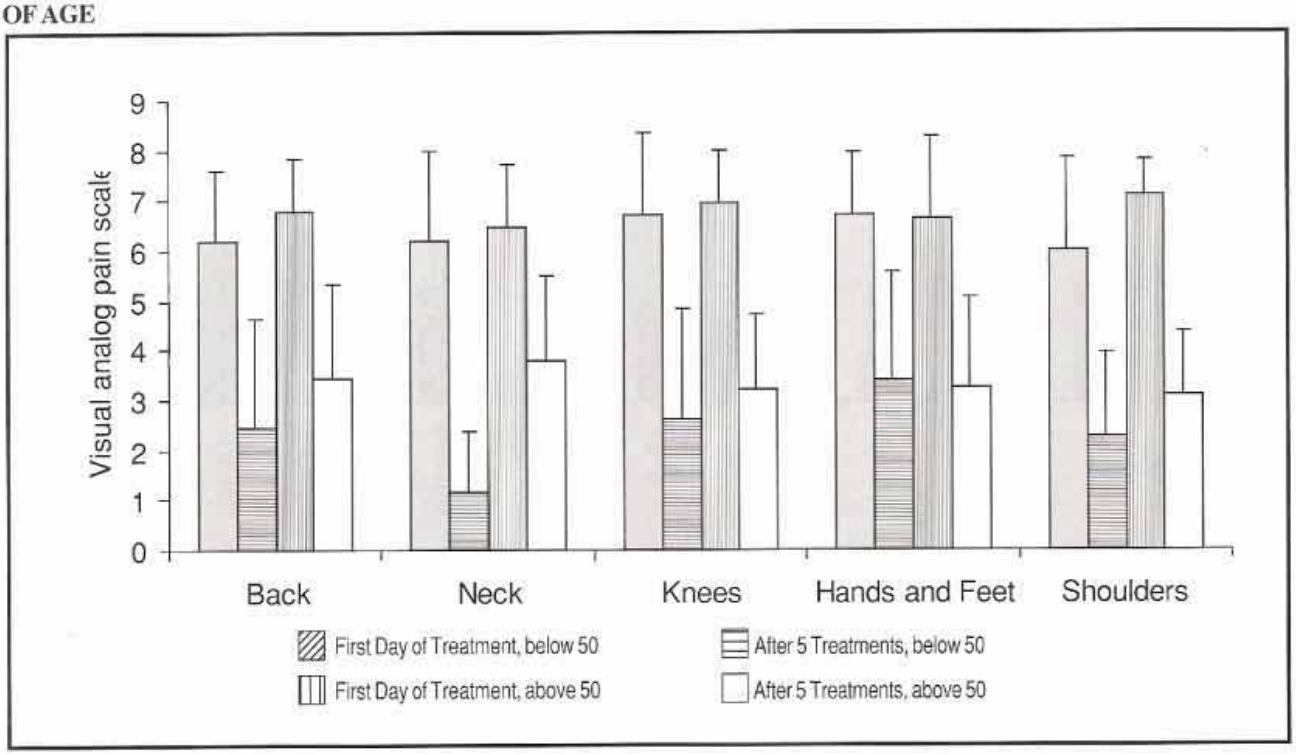
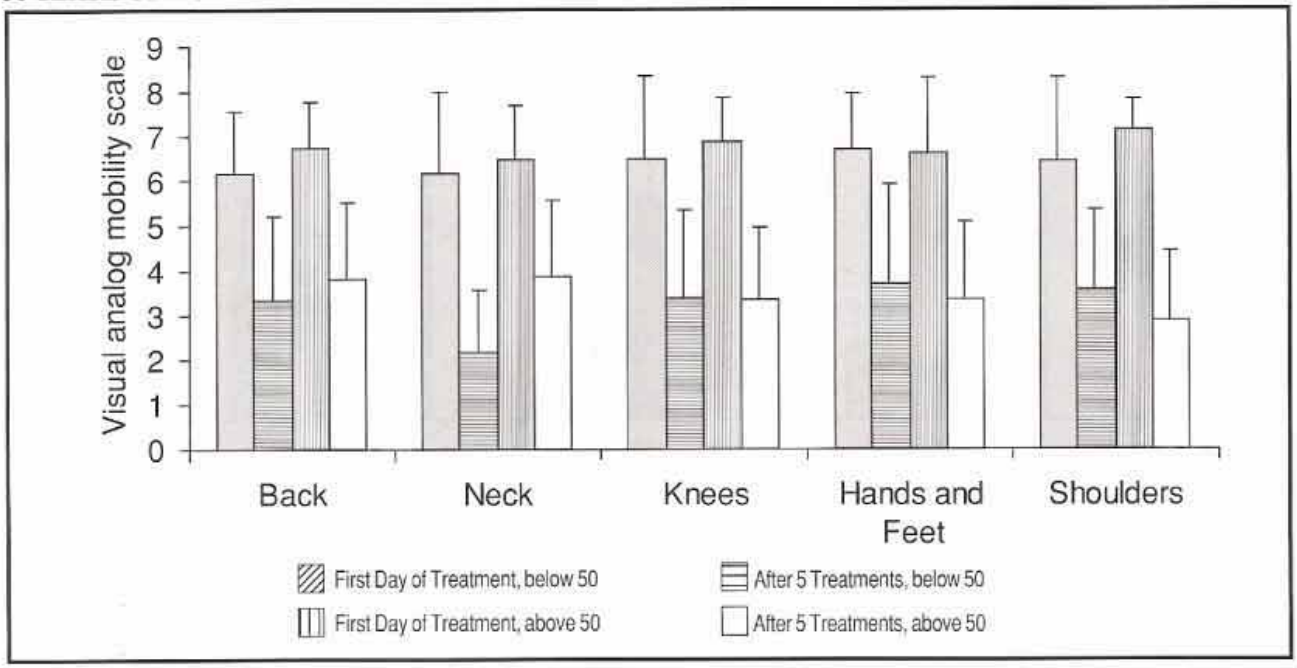


FIGURE III: THE EFFECT OF APS TREATMENT ON VAPS IN PATIENTS ABOVE AND BELOW 50 YEARS OF AGE



large, myelinated A beta fibres are sensory afferents, which are low-threshold mechanoreceptors for light pressure, rubbing and vibration and are classified as the class II, secondary sensory fibres of muscle spindles. These fibres are faster conducting than the slow nonmyelinated, polymodal, C fibres (nociceptors)[15]. Stimulation of these fibres therefore intercepts the stimulation from the C fibres and, according to the gate mechanisms theory, blocks pain perception. Among the opioid peptides, one of the most potent for analgesia is beta endorphin. Three classes of opioids are currently known: the enCephalins, dynorphin and beta endorphin.[16, 21] The discovery of endogenous opioid peptides was one of the most *(cont. pg 24)*

FIGURE IV: THE EFFECT OF APS TREATMENT ON MOBILITY INDEX IN PATIENTS ABOVE AND BELOW 50 YEARS OF AGE



important keys to the understanding of central nervous system pain-modulating circuits[14]. The opiate binding sites relevant to analgesia are found throughout the primary afferents and the neuraxis and are stereospecific and of high affinity[14]. These opioid receptor sites may be stimulated by input from the A beta fibres.[21]

There is a marked increase in mobility with the APS current treatment. It possibly has an action on inflammation, which profoundly assists in improving mobility. A study on osteoarthritis of the knee revealed that APS highly significantly improved mobility in knee flexion in the short duration (8 minutes) and high intensity treatment, and this effect was even further improved one month after the study had been completed[19].

It has also been noted that there are changes that occur spontaneously in the intensity display during treatment with APS therapy. There may be an immediate interaction in the tissue with the current. It also appears that the greater the resistance in the tissues owing to disease, inflammation or swelling, the lower the intensity will register during treatment. As the resistance decreases, the intensity increases, indicating changes in the condition towards normalising the tissue. One can speculate that normal tissue provides less resistance to an electrical current and that diseased or damaged tissue produces a greater resistance to an electrical current. It may therefore be more beneficial, in some patients, to encourage a higher intensity of current in order to affect disease processes.

Injury or disease causes oedema, inflammation, neuronal dysfunction, circulatory disturbance and lack of oxygen supply to the tissues or organ systems. If there is poor transmission or even cessation of activity along the neuron, as a result of injury or disease processes that may affect the Schwann sheath, the system cannot conduct its action potentials, and the homeostatic and regenerative mechanisms are disturbed. Inflammation in tissue promotes the build-up of chemicals, known as the "inflammatory soup" which may also interfere with neural transmission (increases the resistance). This may be caused by mechanical, chemical or electrical disturbance to the neuronal complex.[20]

It is postulated that this therapy produces electrolytic effects in such disturbed areas, and that the current there may result in metabolic catabolism of various inflammatory substances. These products are then transported via the bloodstream to the kidneys, for elimination from the body.

Circulation improves (thermograpy) with the use of APS therapy, and thus antibodies, enzymes, neurotransmitters and hormones are conveyed at an increased rate to the treated area. An increase in the rate of removal of metabolic wastes can also be expected from the above regions. Inflammatory metabolites may be a major cause of pain and thus by removing the cause, pain often diminishes quite rapidly.[20] The improved circulation also produces a reduction in swelling in joints and limbs, and this may also positively affect the lymphatic drainage of that area.

Further research will be required in the future to fully understand the positive mechanisms of electrotherapy on the health of the individual.❐

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