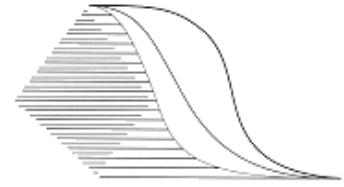


**Centre for Health Services
and Policy Research**



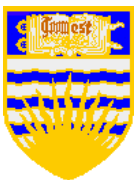
**PULSED SIGNAL THERAPY
FOR MUSCULOSKELETAL
CONDITIONS**

BCOHTA 01:18J

DECEMBER 2001

British Columbia Office of Health Technology Assessment

Workers' Compensation Board of British Columbia



THE UNIVERSITY OF BRITISH COLUMBIA

PULSED SIGNAL THERAPY FOR MUSCULOSKELETAL CONDITIONS

Lyn M Sibley BSc MHA

Researcher
BC Office of Health Technology Assessment
Centre for Health Services & Policy Research
University of British Columbia

Carolyn J Green BHSc (PT) MSc

Research Co-ordinator
BC Office of Health Technology Assessment
University of British Columbia

Craig W Martin MD MHSc

Senior Medical Advisor
Workers' Compensation Board of British Columbia

Ken Bassett MD PhD

Senior Medical Consultant
BC Office of Health Technology Assessment
Centre for Health Services & Policy Research
University of British Columbia

Arminée Kazanjian Dr Soc

Principal Investigator
BC Office of Health Technology Assessment
Centre for Health Services & Policy Research
University of British Columbia

DECEMBER 2001

•

BC Office of Health Technology Assessment

Centre for Health Services and Policy Research
University of British Columbia
429 - 2194 Health Sciences Mall
Vancouver BC
Canada V6T 1Z3
Tel: (604) 822-4810
Fax: (604) 822-5690
bcohta@chspr.ubc.ca
www.chspr.ubc.ca

National Library of Canada Cataloguing in Publication Data

Main entry under title:

Pulsed signal therapy for musculoskeletal conditions

Includes bibliographical references

ISBN 1-896256-17-1

1. Magnetotherapy. 2. Electrotherapeutics I. Sibley, Lyn, 1969 -
II. British Columbia Office of Health Technology Assessment

RM893.P84 2001

615.8'45

C20001-911731-0

© 2001 by British Columbia Office of Health Technology Assessment,
The University of British Columbia. Permission is granted to reproduce
all or any portion of this report, providing acknowledgement is given to
the authors.

FOREWORD

The British Columbia Office of Health Technology Assessment (BCOHTA) was established on December 1, 1990 by a grant from the Province to the University of British Columbia, to promote and encourage the use of assessment research in policy, planning and utilization decisions by government, health care executives, and practitioners. The Office does not participate in policy development for a requesting agency; its role is confined to appraisal of the scientific evidence.

Assessments are performed in response to requests from the public sector such as hospitals, physicians, professional associations, health regions, government; private sector groups such as manufacturers; and members of the general public. One or more of the following criteria are used to determine the priority of an assessment and the level of analysis: (1) the number of users and potential change in quality of life; (2) the acquisition and operating costs to the health care system; (3) the potential to influence provider and consumer behaviour as a result of a review; and (4) the availability of accurate information and appropriate research skills.

Health Technology Assessment projects are conducted by faculty and staff (including medical consultants) who are expert in systematic review methodology. Electronic bibliographic databases and fugitive literature (that is, literature not indexed or distributed publicly) are searched using predefined inclusion and exclusion criteria based on a specific search strategy. The critical appraisal of retrieved evidence includes the formulation of logical and defensible conclusions about the technology under study.

Reports are reviewed internally, and then sent for external review to experts from a variety of academic or clinical disciplines. Comments and suggestions are considered before a final document is produced. Reports are available for public distribution from the Office, by request or inclusion on the mailing list; or from the Centre website.

The strength of BCOHTA's method of systematic review lies in the process of explicitly detailing the methodology and criteria used to produce recommendations, which are based solely on the research evidence. This transparent and reproducible assessment process allows other investigators to review the evidence independently and objectively.

Arminée Kazanjian Dr Soc
Principal Investigator, BCOHTA

Copies may be obtained from:
BC Office of Health Technology Assessment
Centre for Health Services & Policy Research
The University of British Columbia
429 - 2194 Health Sciences Mall
Vancouver, BC V6T 1Z3

Tel:(604) 822-4810
Fax:(604) 822-5690
<http://www.chspr.ubc.ca>

ACKNOWLEDGEMENTS

The observations and suggestions of the following reviewers have been extremely valuable in the preparation of this report, and their contributions are most gratefully acknowledged. Participation in the review process does not imply endorsement, however, and the British Columbia Office of Health Technology Assessment takes full responsibility for the views expressed herein.

Internal Review

Carol Cole RN MSc

Researcher
Centre for Health Services & Policy Research
University of British Columbia
Vancouver British Columbia
Canada

External Review

Hugh Anton MD FRCPC

Head, Division of Physical Medicine & Rehabilitation
GF Strong Rehabilitation Centre
Vancouver Hospital & Health Sciences Centre
Vancouver British Columbia
Canada

Dr Alicia Framarin MD MSc

Chercheure
Agence d'évaluation de technologies et des modes d'intervention en santé
Montréal Québec
Canada

Allan Kozlowski

Physiotherapist
Workers' Compensation Board of BC
Rehabilitation Centre, Clinical Services

Lloyd Oppel BSc MD CCFP (EM)

Chair, Alternative Therapy Evaluation Committee
Vancouver Hospital & Health Sciences Centre
Vancouver British Columbia
Canada

TABLE OF CONTENTS

Foreword	iii
Acknowledgements	iv
Table of Figures	vi
EXECUTIVE SUMMARY	vii
1 INTRODUCTION	1
2 ANALYTICAL FRAMEWORK	2
3 BACKGROUND	3
3.1 Pulsed Electromagnetic Energy devices	3
3.2 Mechanism of action	4
3.3 Clinical conditions	5
3.4 Identifying the technology	5
4 METHODOLOGY	9
4.1 Criteria for considering studies for review	9
4.2 Exclusion criteria	10
4.3 Search strategies	10
4.4 Evaluative framework	12
5 RESULTS	13
5.1 Search findings	13
5.2 Critical analysis - Menkes <i>et al</i> (1998)	13
6 DISCUSSION	16
7 CONCLUSIONS	18

APPENDICES

Appendix A Prioritizing criteria applicable to Pulsed Signal Therapy 19
Appendix B Patents 20
Appendix C Search strategy 22
Appendix D BCOHTA intervention study appraisal form 24
Appendix E Excluded articles 26
Appendix F Technical specifications of devices in RCTs 28
Appendix G Randomized controlled trials of non-PST PEME devices 30

BIBLIOGRAPHY 32

REFERENCES 37

FIGURES & TABLE

Figure 1 Pulsed Electromagnetic Field Devices 8
Figure 2 Pulsed Signal Therapy with alternating rectangular pulses 8
Table 1 Summary of secondary outcomes – Menkes *et al* (1998) 15

EXECUTIVE SUMMARY

Findings

This systematic review examined whether pulsed signal therapy (PST) provides a significant effectiveness and safety therapeutic advantage over other musculoskeletal-injury treatment devices that use magnetic pulses to induce electrical current in injured tissue.

There are no published controlled, clinical trials showing that PST provides a clinical advantage versus placebo or other pulsed electromagnetic energy devices. The one small, unpublished randomized controlled trial of PST that could be located provides no valid evidence that PST is more effective than placebo at treating the symptoms of osteoarthritis of the neck or knee.

Pulsed Signal Therapy

PST is a specific form among a class of devices which use pulsed electromagnetic energy (PEME) to induce electrical current which is claimed to promote healing in injured or diseased tissues.

PEME devices share several basic features deriving from the transmission of electromagnetic energy, including intermittent electrical current, non-contact with the skin, and having no detectable thermal effect.

PEME has been used clinically in Europe, Canada, and the United States. Currently, the use of PST in North America is limited to facilities in Mexico (Tijuana), and Canada (Vancouver). In April 2000, PST was approved (without review of effectiveness evidence) by Therapeutic Products Directorate of Health Canada Health Product and Food Branch. The extent to which it has subsequently gained acceptance is unknown.

The PST Centers state that PST is distinct from pulsed electromagnetic field therapy (PEMF), a specific type of PEME therapy. According to the Centers, PST has pulses of variable intensity and frequency, while the pulses of PEMF are of constant intensity and frequency. It is not known whether these differences produce different clinical effects. The PST Centers make claims about the difference in favourable clinical outcomes from PST versus other PEME devices, and the cost of the services they provide is based on this assumption of difference.

Methodology

This study systematically reviewed the literature for randomized controlled trials that met the following criteria:

- assessment of individuals with non-fracture musculoskeletal conditions;
- application of Pulsed Signal Therapy (PST) for the purpose of effecting health benefits;
- measurement of the health outcome pertaining to the effect of pulsed or oscillating magnetic fields; and
- comparison of PST with an alternative PEME device.

An electronic search of the literature was undertaken, aimed at ensuring comprehensive coverage of both traditional and ‘grey’ literature. A fugitive literature search was undertaken to identify documents not referenced in technical reports, unpublished material, conference proceedings, theses, as well as government papers and policy documents not controlled by commercial publishers.

All articles which met the inclusion/exclusion criteria were critically analysed by two researchers. Any discrepancies between the reviewers were resolved through discussion.

Results

Thirty-nine articles were identified and retrieved. Twelve of these were randomized controlled trials of therapy with a pulsed electromagnetic energy device. Of these, eleven trials were excluded because they were not studies of PST, but of other PEME devices. Only one of the identified trials was an assessment of PST. This trial was placebo-controlled and not a comparison with any other form of PEME.

The one included trial was an unpublished report of a study conducted in France by Menkes *et al* in 1998. The sample used in this trial was small, and the analysis performed was without adjustment for multiple comparisons examining significant outcomes. The reviewers agree with the study authors that no valid conclusions can be drawn from this trial. Larger, longer, and better-conducted RCTs are needed to establish effectiveness of PST versus placebo.

1 INTRODUCTION

The Workers' Compensation Board (WCB)* Technology Assessment Committee† in collaboration with the BC Office of Health Technology Assessment (BCOHTA) examined the effectiveness and safety evidence regarding pulsed signal therapy (PST) in the treatment of non-fracture musculoskeletal conditions. PST is a specific form among a class of devices which use pulsed electromagnetic energy to induce electrical current which is claimed to promote healing in injured or diseased tissues. Induction of electrical current means that the device has no electrodes in direct contact with the patient. Affected tissue is instead situated within an electrical 'inducing' magnetic field.

Some types of electromagnetic inducing technologies are currently used in British Columbia. Under the provincial health insurance plan, they are all paid for as part of a general therapy code. The relevant hospital department or private practitioner is reimbursed for the session, regardless of the technique or technology used. A hospital physiotherapy department may, for example, use a form of electromagnetic inducing device with or without other technologies such as ultrasound, heat therapy, or massage, in the course of a treatment session. A series of 10 treatment sessions with a physiotherapist currently costs the WCB approximately \$305 CDN.

The WCB has received requests from the Vancouver Certified Pulsed Signal Therapy Center to pay specifically for PST treatment within the Center. The WCB Technology Assessment Committee selected this modality as appropriate for priority review, primarily because this class of devices could potentially be used in many treatment programs for work-place injuries. The Committee criteria and their application to PST are summarized in **Appendix A**.

* The Workers' Compensation Board (WCB) of British Columbia is the principal payment agency for work-related injuries in the province. The WCB funds rehabilitation and a range of other services, as well as providing compensation and other health care benefits.

† In collaboration with BCOHTA, the WCB recently established a Technology Assessment Committee, mandated to determine the effectiveness, safety, and cost of new and improved technologies used for diagnosis and treatment of work-related injuries in the province.

A course of treatment at the PST Center costs \$2,000 CDN, and includes “nine one-hour treatment sessions, ... consultation and evaluation by the physician, and all associated medical examinations.”¹ WCB administrators consequently asked whether clinical evidence of patient benefit was sufficient to justify this expenditure.

In consequence, this systematic review does not examine whether PST or similar devices provide a therapeutic advantage versus placebo or alternate forms of technology, such as ultrasound. Instead, the review focuses specifically on PST, and follows a relative effectiveness and safety framework, that is, consideration of whether scientific evidence supports PST versus other devices in the same therapeutic class. The question of benefit includes two components: *i*) How does PST differ from less expensive alternatives; and *ii*) which patients have been shown to benefit?

Research question

Having regard to these component issues, the principal question addressed in the systematic review was formulated as follows:

Does Pulsed Signal Therapy (PST) provide a significant effectiveness and safety therapeutic advantage over other musculoskeletal-injury treatment devices that use magnetic pulses to induce electrical current in injured tissue?

3 BACKGROUND

3.1 Pulsed Electromagnetic Energy devices

A number of different devices have been used to expose injured or diseased parts of the body to pulsed electromagnetic energy. These devices have numerous names, including: ‘pulsed diathermy’, ‘pulsed electromagnetic field’, ‘pulsed short-wave’, ‘pulsed high-frequency electromagnetic energy’, ‘Diapulse’, ‘oscillating magnetic fields’, and ‘pulsed signal therapy’. In this report, all devices in this class are referred to as ‘pulsed electromagnetic energy’ (PEME) devices.

PEME devices share several basic features deriving from the transmission of electromagnetic energy, including intermittent electrical current, non-contact with the skin, and having no detectable thermal effect.

PEME devices are not considered complex electrical equipment, nor are they costly to construct. The apparatus usually employs a cylindrical coil of wire, housed so as to surround whatever body part is being targeted. For example, the technology studied in two randomized controlled trials, pulsed electromagnetic field (PEMF), is described by authors as a device that “consisted of 3 integrated components, a magnetic field generator, an electronic interface, and a segmented single toroid coil with annular windings that produced pulsed DC elliptical magnetic fields. The system used a coil current of <2 A with 120 V.”²

An electrical engineer³ consulted for this report estimated that it would take a suitably-qualified person a few hours to assemble a PEMF device, constructed from standard components. If a pre-assembled magnetic coil were not readily available, a suitable coil could be wound by hand. A variable-frequency electrical-wave generator of requisite accuracy and variability range would be the most expensive component. Since the generator signal is likely to be of insufficient power rating to drive the electromagnet, an electrical amplifier would also be required. Altogether, the estimated total cost of materials is likely to be less than \$400.00.³

3.2 Mechanism of action

Several theories have been advanced to explain how PEME promotes healing and relieves pain:

- “ ... the electromagnetic energy ‘stirs’ ions, molecules, membranes and perhaps cells thus speeding up phagocytic activity, enzymatic activity, transport across membranes and so forth.”⁴ (p267)
- “Some depolarization of the cell membrane is often associated with cell dysfunction and electrical potentials develop during wound healing. The membrane potential is also involved in the control of cell division and hence in the control of growth, development and repair. It has been proposed that the electromagnetic field could influence the flow of the ions through the membrane and therefore restore the normal cell potential in some damaged cell.”⁴ (p267)
- “ ... cells are capable of absorbing energy from oscillating electrical fields of defined frequencies and amplitudes, and making use of this energy for chemical work.”⁴ (p267)
- “ ... pulsed ultrasound has been shown to accelerate healing at different rates with different intensities and pulse lengths. It is reasonable to suppose that both electromagnetic and mechanical pulsing have similar effects at a subcellular level, a piezoelectric link. Piezoelectric effects are known to occur in the tissue, for example mechanical stress on bone leads to a redistribution of charges. It is argued that the importance of pulsing may lie in the fact that brief pulses of high intensity will not necessarily have the same effect as an identical quantity of energy applied continuously.”⁴ (p267)
- “Beneficial effects are simply due to the recognized effects of very mild heating ... At microscopic level, ‘heat’ is simply the kinetic energy of small particles and is likely to vary from place to place. Thus, the addition of small amounts of energy to the tissues could well increase local particulate motion.”⁴ (p267)
- Studies of electrical phenomena in cartilage suggests the phenomenon may stimulate chondrocyte synthesis of matrix components.⁵
- Pulsed electromagnetic energy therapy is “a form of therapy that involves directing a series of magnetic pulses through injured tissue. Each magnetic pulse induces a tiny electrical signal that stimulates cellular repair.”⁶

Such theories, whatever their merit, are not immediately pertinent for present purposes, since it is the therapeutic effect of these devices which is at issue. Uncertainty concerning the mechanism of action would not undermine any outcome benefit found by properly conducted clinical trials.

3.3 Clinical conditions

Pulsed electromagnetic energy (PEME) was initially used in the early 1970s for the treatment of soft tissue injuries,⁵ and in the 1980s to promote skin ulcer healing.⁷ PEME is most accepted as a means of promoting bone and cartilage repair, particularly in the event of delayed healing such as non-union fractures, but the technology has also been used in the treatment of the following non-fracture musculoskeletal conditions:

- nerve damage^{5,8}
- recovery from soft tissue injuries of the ankle⁵
- recovery from avascular necrosis of the femoral head⁹
- recovery from rotator cuff tendonitis⁷
- analgesic reaction in cervical and knee arthrosis^{2,10}
- avascular necrosis of hips^{11,12}
- Legg-Perthes' disease¹³

PST Centers' focus is on the treatment of non-fracture musculoskeletal conditions.

PEME has been used clinically in Europe, Canada, and the United States.^{2,9,10,11} Currently, the use of PST in North America is limited to facilities in Mexico (Tijuana), and Canada (Vancouver). These are listed on the PST Centers' website, which also offers to provide requesters with the location of facilities operating outside North America.¹⁴ PST has had regulatory approval for use in Canada since April 2000. The extent to which it has gained acceptance is unknown.

3.4 Identifying the technology

3.4.1 Licences

Health Canada, Health Protection Branch

PST has received approval from the Therapeutic Products Directorate (Medical Devices Bureau), Health Canada, as a Class II Device. The licence is listed as Pulsed Signal Therapy System with the manufacturer Bio-Magnetic Therapy Systems GMBH, licence # 19291.

In order to receive a licence for a medical device in Canada, the manufacturer must attest to have evidence that the device “shall be effective for the medical conditions, purposes and uses for which it is manufactured, sold or represented.”¹⁵ The manufacturer need not actually provide the effectiveness evidence, since it is not assessed by the regulatory body.

US Food and Drug Administration

The website of the Pulsed Signal Therapy Centers states that the “technology is available in most important industrialized countries in the world but is not yet approved by the FDA [United States’ Food and Drug Administration] or available in the United States.”¹⁶

Under the FDA guidelines, PST would be rated as a Class III device.

“Pre-market approval is the required process of scientific review to ensure the safety and effectiveness of Class III devices. Not all Class III devices require an approved pre-market approval application to be marketed. Class III devices which are equivalent to devices legally marketed before May 28, 1976 may be marketed through the pre-market notification [510(k)] process until the FDA has published a requirement for manufacturers of that generic type of device to submit pre-market approval data.”¹⁷

It is not clear from the available information whether PST would require FDA ‘pre-market approval’ or ‘pre-market notification’. The FDA’s Center for Devices and Radiological Health (CDRH) states:

“Both domestic and foreign manufacturers must list their devices with FDA if the devices are in commercial distribution in the United States ... Neither registration nor listing constitutes FDA clearance or approval for marketing or commercial distribution in the U.S. Unless the device is exempt, a pre-market notification submission [510(k)] or a premarket approval application (PMA) is required before commercial distribution commences. Registration of a device establishment or submission of device listing does not in any way denote approval of the establishment or its products by FDA.”¹⁸

A search of the CDRH database found a registration listing for a “PST System Model Mark II” with the company Bio-magnetic Therapy Systems, Inc. The device is not found in either the ‘pre-market approval’ or ‘pre-market notification’ databases, however, indicating that to date, PST does not have FDA approval.

3.4.2 Patents

Types of PST devices are patented in both Canada and the United States. A detailed description of the identified patents is provided in **Appendix B**.

There is no Canadian patent for any device specifically named “pulsed signal therapy”, but two patents are held by Bio-magnetic Therapy Systems, Inc. for devices that appear to be PST devices. The technology in the two patents (**Appendix B**) seems identical, distinguished only by mode of administration. The mode of administration in the first (#2,082,170 – *Magnetic field therapy and apparatus*) is a table or bed on which the patient lies while one of 3 different-sized PST devices are moved to the injured/diseased body part. The second mode of administration (#2,330,690 – *An apparatus for the treatment of disorders of issue and /or the joints*) is a portable structure which fits around neck or jaw to administer PST to that area.

There are eight US patents under Markoll, the inventor of PST devices, for use of this technology on humans. One is the original patent (#5,131,904), to which the subsequent continuation patents refer back. It appears that the same technology is used in all cases. The patents differ in the condition treated, the body part to which treatment is applied, or the apparatus that supports the patient while treatment is administered. As mentioned previously, none of these devices is identified as having FDA approval.

3.4.3 Definition of technology

The material provided to WCB by the Vancouver PST Center clearly states that PST is distinct from PEMF, another PEME device:

“PEMF, which works with pulsed electromagnetic fields, utilizes a direct current oriented, constantly repeating signal. This is transmitted at a particular intensity and particular frequency. The pulse is constant for the duration of its application to the joint.

PST should be regarded as a logical extension of PEMF... In contrast to PEMF, PST operates by specific physiological changing rectangular pulses as stimuli, which are transmitted in a programmed alternating fashion that mimics the body’s natural streaming potentials for the duration of the one-hour treatment. The intensity of these rectangular pulses lies predominantly in the range of 0.5 to 1.5 militesla. The frequency ranges from 10 to 20 Hz. Thus, PST works at relatively low biological frequencies as well as in a low energy domain, with regard to field strength.”¹⁹

Figure diagrams are included in the Centers material which illustrate the contrasting intensities of field strength and frequency. (Figures 1 & 2)

Figure 1: Pulsed Electromagnetic Field Devices ¹⁹

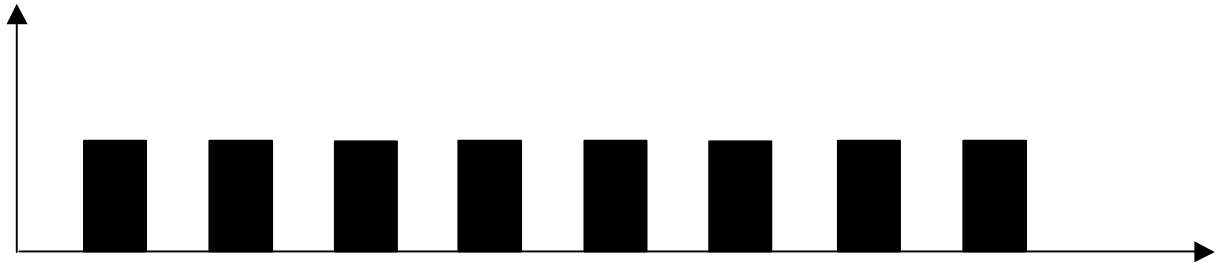
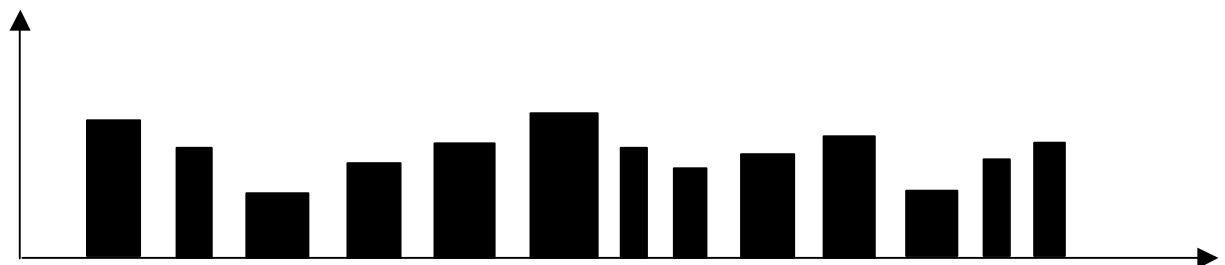


Figure 2: Pulsed Signal Therapy with alternating rectangular pulses as physiological stimuli ¹⁹



In consultation with a WCB engineer, it is accepted that PST may indeed differ from PEMF and/or other PEME devices.³ The principal point of difference is that PST may deliver a variable intensity in the pulsed signal, as opposed to the fixed intensity of the PEMF pulsed signal.

While this distinction is noted, the present systematic review does not seek to evaluate whether the various devices have the electromagnetic properties claimed for them. The aim, rather, is to determine the clinical outcome of the devices as identified. In other words, accepting that PST is distinct from PEMF (or all PEME devices), the question is: what is the clinical effectiveness difference as a result of the distinction?

4 METHODOLOGY

A systematic search and appraisal of the literature was conducted using the following criteria and parameters.

4.1 Criteria for considering studies for review

4.1.1 Participants

Individuals with non-fracture musculoskeletal conditions:²⁰

- osteoarthritic defects of the shoulder, elbow, hand, thumb, and fingers
- ligament defects, including ‘tennis elbow’ and ‘golfer’s arm’
- shoulder defects such as torn rotator cuff and ‘pitcher’s shoulder’
- carpal-tunnel syndrome and related repetitive-stress injuries
- injured ligaments and calcium deposits
- tendonitis
- osteoarthritic defects of the knee
- anterior cruciate ligament injuries
- knee-strain and knee-cap problems
- meniscus degeneration
- foot and ankle joint problems
- Achilles’ tendon injuries
- splayfoot and heel spurs
- degenerative osteoarthritic defects
- lower-back problems (lumbago)
- slipped-disc, sciatica, muscle spasm
- neck-whiplash syndrome
- bursitis

4.1.2 Intervention

Studies were included if interventions were described as the application of pulsed signal therapy (PST) for the purpose of effecting health benefits. A technology is classified as PST if it is called PST by the authors, or if it is described as having the technological features that are unique to PST, specifically, variable pulse intensity and frequency.

4.1.3 Outcome measures

Studies were included if they reported any measure of a health outcome pertaining to the clinical effect of pulsed or oscillating magnetic fields, including:

- increased healing
- reduced swelling
- increased mobility, and
- reduced pain.

4.1.4 Types of Studies

All randomized controlled trials involving PST were retrieved. Only trials comparing PST with an alternative PEME device were critically appraised.

4.1.5 Language

English and non-English articles were included.

4.2 Exclusion criteria

Research was excluded that:

- reported physiological or laboratory parameters only;
- pertained to malignant conditions;
- was conducted on animal models or in vitro;
- dealt solely with fracture non-union conditions;
- looked at transcutaneous electrical nerve stimulation (TENS/TNS);
- was conducted on post-surgical patients;
- dealt with epiphyseal disease (eg: Legge-Perthes' disease);
- did not use PST.

4.3 Search strategies for identification and retrieval of information

An electronic search of the literature was undertaken, aimed at ensuring comprehensive coverage of both traditional and complementary literature.

Several medical bibliographic databases were searched via DIALOG to ensure coverage of traditional and complementary literature: Medline, Embase, Biosis Previews, SciSearch, Mantis, Allied & Alternative Medicine, SPORTdiscus, TGG Health & Wellness, CAB Health, HealthSTAR, Conference Papers Index, and Elsevier Biobase. Databases were searched from 1980 to 2000.

All terminology was reviewed by Technology Assessment Committee members. Search terms were selected in an effort to reflect the diverse terms and terminology used to refer to pulsed signal therapy. Keywords such as “electromagnetics”, “magnetic”, or “electrical” were combined with “fields”, “therapy”, or “stimulation” and then further combined with “pulse”, “pulsed”, or “pulsing”. These keywords were limited to title or descriptor fields, in order to improve the relevance of the search results. In addition, the phrase “pulsed signal therapy” was searched throughout the body of the record (i.e. title, key words, abstract).

A range of synonyms was selected to cover possible soft tissue disorders. For example, keywords such as “tendin”, “tendon”, “meniscus”, or “ligament”, plus many others were searched in title and descriptor fields. This set was combined with the search results from the set of pulsed signal therapy.

To identify research methodologies used to evaluate the treatment, a range of keywords was searched throughout the body of the record. Keywords included “trial”, “cohort”, “multivariate analysis”, and “expert panel”. These results were then combined with the results from the previous sets.

A search was conducted by authors: DH Trock, C Hershler, R Markoll, S Kornhauser, A Binder, T Zizic, and J Moffett. The results of the author search were not limited by date.

A fugitive literature search was undertaken to identify documents not referenced in technical reports, unpublished material, conference proceedings, theses, as well as government papers and policy documents not controlled by commercial publishers.

Full details of the search strategy and fugitive sources used are given in **Appendix C**.

Search results were reviewed independently by the authors. Each applied the inclusion and exclusion criteria to the identified literature. Disagreements were resolved by discussion. All articles that appeared to meet the inclusion criteria were requested in full text, and again appraised independently by the authors. The reference lists from the articles retrieved in the search were reviewed to identify further relevant citations. All the articles obtained are listed in the **Bibliography**.

4.4 Critical appraisal

All articles which met the inclusion/exclusion criteria were critically analysed by two members of the Technology Assessment Committee, using an Intervention Study Appraisal Form (**Appendix D**), developed by the BC Office of Health Technology Assessment following the work of Sackett *et al.*,²¹ and Schechter & LeBlanc.²² Any discrepancy in the findings of reviewers was resolved through discussion.

5 RESULTS

5.1 Search findings

Thirty-nine references were identified and retrieved. The inclusion/exclusion criteria were applied, and based on the findings, 27 were excluded (**Appendix E**), and 12 were found to be randomized controlled trials of therapy with a pulsed electromagnetic energy device.

Assessment of the descriptions and technical specifications are presented in **Appendix F**.

Based on our inclusion/exclusion criteria, 11 of the 12 trials were excluded because they were not studies of PST, but of other PEME devices. The 11 excluded trials were:

- four trials evaluating pulsed electromagnetic field (PEMF) therapy (previously distinguished from PST in **Section 3.4.3**);
- two trials of Diapulse, two of pulsed electromagnetic therapy (PEMT), and one of pulsed short wave (PSW), none of which were called or described as PST, or described as operating “by specific physiological changing rectangular pulses”¹⁹(*p* 2); and
- two were non-English articles that, when translated, did not describe the variable pulses unique to PST.

There were no trials comparing PST with an alternative PEME device. Only one of the identified trials was an assessment of PST, Menkes *et al*, described below. This trial was placebo-controlled and not a comparison with any other form of PEME. The 11 trials of non-PST devices are described in **Appendix G**.

5.2 Summary of Menkes *et al* (1998)²³

This unpublished report is a description of the study conducted in France by Menkes *et al*²³ in 1998.

5.2.1 Purpose

This trial assessed the effectiveness and tolerance of pulsed signal therapy (PST) for painful osteoarthritis.

5.2.2 Design

This is a randomized, placebo controlled trial. The study was described as double-blinded, although the authors do not specify how blinding was achieved or who was blinded.

5.2.3 Population

Forty patients older than age 50 with painful osteoarthritis (according to the criteria of the American College of Rheumatology, for the diagnosis of osteoarthritis of the knee) were randomized into a treatment group (21 patients) and a placebo control group (19 patients). There was no sample size / power calculation given to support this number. Seven control, and eight treatment patients withdrew prior to the 3-month follow-up evaluation.

5.2.4 Treatment

Each patient had 9 one-hour sessions of PST on consecutive days. No description of the placebo is given.

5.2.5 Primary outcome measures

The primary outcome was patient assessment of spontaneous pain at rest and in motion using a visual analogue scale (VAS), with 0 being no pain and 100 being the highest level of pain.

5.2.6 Secondary outcome measures

- Patient assessment of spontaneous pain at rest and in motion using a verbal scale;
- assessment of pain or discomfort in everyday life (24-point algofunctional Lequesne index); and
- quality of life (SF-36).

5.2.7 Analytical method

Placebo and treatment groups were compared at each follow-up point, and analysis of variance by rank was performed to account for the effect of time. No analysis of the change from baseline within each group was conducted.

For the primary outcome variable, each analysis was performed in two ways: 1) comparing the values recorded at each patient evaluation (values recorded); and 2) recording the last values carried forward to subsequent measurement times on those who withdrew early (end-point).

5.2.8 Results

No significant differences in clinical characteristics were found at baseline. The high rate of withdrawal (37.5%), however limits the validity of the results.

The authors reported a small difference between the active treatment group and the placebo group in the primary outcome variables at two of the three assessment points. They found a significant difference in the mean VAS measurement of pain in motion at day 9 (41.8±23.6 vs. 59.5±24.2; p=0.02), and month 3 (32.3± 23.8 vs. 59.9± 34.0; p=0.03), in the recorded value analysis. Similar results were found in the end-point analysis. There were no significant differences found in any of the analyses of pain at rest.

Secondary outcome measures were compared between the two groups for each outcome at baseline, day 9, month 1, and month 3. In all, at least 76 tests of significance were conducted. Of these, 15 showed a statistically significant difference (p < 0.05) between the treatment and placebo groups; there was no adjustment made for the number of comparisons done. Because of the small sample size (n=40), this study is unable to identify any small differences that may exist between the placebo and treatment groups.

The findings for the secondary outcome measures support the primary outcome findings with virtually no difference between the two groups. These outcomes are summarised in **Table 1**.

The Technology Assessment Committee reviewers agree with the study authors that no valid conclusions can be drawn from this trial. Larger, longer, and better-conducted RCTs are needed to establish effectiveness versus placebo.

Table 1: Summary of secondary outcomes – Menkes *et al* (1998)²³

Measure	Outcome Findings
Verbal pain scale (rest and motion)	No differences found at any point
Lequesne functional index	Significant differences favouring PST at month 3 only
Physician assessment of effectiveness	A significant difference favouring PST at day 9 only
Patient assessment of effectiveness	No differences found at any point
Percentage of subjects improved by ≥ 30%	No differences found
Quality of life (SF-36)	Differences found in the general health and moral health scales at month 3, and the emotional function scale at all points

6 DISCUSSION

PST is one of a number of different pulsed electromagnetic energy (PEME) devices. Assessment of the technical specifications of PST shows that, as compared with other PEME devices, there are differences in specific parameters. PST has a different combination of pulse duration, frequency, and magnetic-field strength, compared to any other PEME device studied. The random nature of the pulses and pauses in PST is also said to be unique. It is not known, however, whether these differences produce different clinical effects. The PST Centers make claims about differences in clinical outcomes of PST as against other PEME devices, and the cost of the services they provide is based on this assumption of difference.

Particular confusion exists regarding the distinction between PST and PEMF. Studies of PEMF are often cited by PST Centers' literature and publications in support of PST.

The Research Overview section of the Pulsed Signal Therapy Centers' website states that "Researchers at Yale University School of Medicine began clinical trials on a Pulsed Signal Therapy device in 1990 to see how well this technology would work on humans."²⁴ Although not cited by name, these are evidently the studies by Trock *et al.*^{2,10}

Hershler *et al.*,⁶ in their report of a case series of patients using PST at the Vancouver PST Center, also cite Trock *et al.*'s studies in support of efficacy claims. They state "Randomized, placebo controlled, double blind studies showed that between 70 and 80% of osteoarthritis patients who received PST experienced a significant reduction in chronic pain".⁶ (p168)

The Trock *et al.*² study is an investigation of PEMF, and therefore was excluded from critical appraisal in this report. It is, however, discussed at this point, since the study may contribute to the evidence of effectiveness of the class of PEME devices that include PEMF and PST.

Trock *et al.*² conducted a double-blind, randomized, placebo controlled trial of PEMF on 167 patients with osteoarthritis of either the knee or cervical spine. The outcome of interest was reduction of pain (evaluated with a VAS and physician assessment), and improvement in activities of daily living (evaluated with a patient questionnaire). At the end of treatment, the mean level of improvement from baseline was always higher for the treated patients than the placebo group.

The difference was statistically significant, favouring PEMF for pain (27.21 vs. 14.03; $p=0.005$), and pain on passive motion (0.70 vs. 0.41; $p=0.045$), but not ADL difficulty and joint tenderness. One month following treatment, statistically significant differences favouring PEMF were found in pain (24.77 vs. 11.86; $p=0.018$), pain on passive motion (0.78 vs. 0.16; $p<0.001$), and joint tenderness (0.73 vs. 0.21; $p=0.001$). In all, there were 110 tests of significance favouring PEMF reported, of which 25 were significant ($p < 0.001$).

Many participants in Trock *et al* received co-interventions at the time of the trial, including pain medications and physiotherapy, which were not controlled for in the study analysis. Furthermore, while the physician assessing the patient was blinded to the random assignment of each patient, the therapy technician was not. It is not known how well the patients were blinded.

The efficacy references made by PST Centers imply that PST and PEMF are the same, and yet distinct. The PST Centers claim that the effectiveness evidence for PEMF supports PST, which may be the case. The claim that PST is distinct and preferable to PEMF and the class of PEME devices is unfounded, however.

Electromagnetic devices are numerous, their similarities and differences confusing, and research papers investigating potential clinical benefits are substantial in volume. This evidence is difficult to organize, in large part because electromagnetic devices are almost always only one component of a complex therapeutic program. It should also be noted that the inclusive payment practice already mentioned makes utilization analysis from WCB administrative claims data virtually impossible.

PST is patented and has been approved for marketing in Canada, but the technology has not received regulatory approval from the Food and Drug Administration (FDA) in the United States. The FDA, unlike its Canadian counterpart, evaluates effectiveness evidence. The patents and licences of PST were investigated to see if they would clarify the contradiction discussed above. Other than delineating the technical distinction (outlined in 3.4.3 above), no other assertion of difference was found to describe how PST might confer a distinct therapeutic advantage.

7 CONCLUSIONS

There is no trial demonstrating that PST provides a significant effectiveness and safety therapeutic advantage over other musculoskeletal injury treatment devices that use magnetic pulses to induce electrical current, in injured tissue. There is also little evidence that PST provides a significant effectiveness and safety therapeutic advantage over placebo.

There are no published, controlled trials comparing PST with generic PEME therapies. Only one small (n=40), short (3 months), unpublished randomized controlled trial of PST could be located (Menkes *et al*²³), which studied its use in osteoarthritis of the knee. This study provides no valid evidence that PST is more effective than placebo at treating the symptoms of osteoarthritis.

There are no published controlled, clinical trials showing that PST provides a clinical advantage versus placebo or other PEME devices.

APPENDICES

APPENDIX A: **Prioritizing criteria applied to Pulsed Signal Therapy**

Criteria	Extent to which criteria met
1. Number of users	Many WCB patients with musculoskeletal injuries (more than 100,000 patients per year)
2. Potential change in health outcomes	A decrease in morbidity due to work related injuries
3. Acquisition and operating costs to the health care system	WCB rehabilitation related reimbursements for the services of physiotherapists, massage therapists, chiropractors, and physicians.
4. Potential to influence provider and consumer behaviour as a result of a review	Potential points of influence are the professional regulatory bodies, reimbursement and provider decisions
5. Availability of accurate information and appropriate research skills	Some scientific evidence is available that is not expected to exceed the resources of the Technology Assessment Committee of the WCB

APPENDIX B: Patents

Canadian Patents *

1. #2,082,170 – Magnetic field therapy and apparatus (July 1996).

“Process involves treating organs by applying a magnetic field by way of an annular coil surrounding the organ, the coil being energized by a pure DC voltage having a rectangular wave form pulsing at the rate of 1-30 CPS. The invention also includes an apparatus comprising a body support encompassed by an annular coil energized as above. The coil is mounted on a carriage running on tracks adjacent the body support.”

2. #2,330,690 – An apparatus for the treatment of disorders of tissue and /or the joints (November 1999).

“An apparatus for the treatment of disorders of tissue and/or the joints in the area of the jaw or neck of the patient, particularly for the treatment of periodontosis, is depicted, wherein the apparatus comprises a housing that surrounds at least the area of the jaw or neck to be treated. A number of coils is also provided for generating at least one electromagnetic field which can be applied to the area to be treated. The coils are arranged in the interior of the housing.”

U.S. Patents †

3. #5,131,904 – Treatment of arthritis with magnetic field therapy and apparatus therefore (July 1992).

The abstract given in this patent description is the same as that given for Canadian patent # 2,082,170 (1. above), and US patent #5,842,966 (6. below). The major difference appears to be that this patent was issued to the inventor, independent of the company, Bio-magnetic Therapy Systems, Inc. and although this patent describes the table that is used to administer the therapy, it is not mentioned in the list of claims. A copy of the Certificate for United States Patent for this patent was given to WCB by the Vancouver PST Center.

4. #5,387,176 – Treatment of acute diseases as caused by the sports-type injuries of the musculoskeletal system (excluding fractures) with magnetic field therapy (February 1995).

“Process involves treating acute diseases of a body organ of the musculoskeletal system by applying a magnetic field by means of an annular coil surrounding the diseased organ, the coil being energized by a pure DC voltage having a rectangular wave form pulsing at the rate of 1-30 CPS.”

* Information of patents issued in Canada can be found at The Canadian Intellectual Property Office: http://strategis.ic.gc.ca/sc_mrksv/cipo/welcom/welcom-e.html

† Information of patents issued in the United States can be found at the United States Patent and Trademark Office: <http://www.uspto.gov/patft/index.html>

5. #5,453,073 – Apparatus for treatment of diseased body organs with magnetic field therapy (September 1995).

The abstract for this patent is the same as for Canadian patent #2,082,170 (1. above).

6. #5,665, 049 – Treatment of acute diseases as caused by the sports-type injuries of the musculoskeletal system (excluding fractures) with magnetic field therapy (September 1997).

Same as US patent #5,387,176 with the addition of a claim stating that “the diseased body organ is disposed eccentric of the axis of the coil.”

7. #5,669,868 – Treatment of wrinkled discolored or aging skin with magnetic field therapy (September 1997).

“Process involves treating skin by subjecting it to magnetic therapy by an annular coil energized by pulsed DC voltage having rectangular wave from pulsing at the rate of 1-30 CPS, the coil producing a field of under 20 gauss.”

8. #5,842,966 – Treatment of arthritis with magnetic field therapy (December 1998).

This is the same device as described for the Canadian patent #2,082,170 and US patent #5,131,904 (1. & 3. above).

9. #D407,819 – Treatment bed (April 1999).

This “Design Patent” describes a treatment bed similar to the one in other patents.

10. #6,048,302 – Apparatus for the treatment of disorders of tissue and/or the joints (April 2000)

This is the same device as described for the Canadian patent #2,330,690 (2. above).


APPENDIX C: Search strategy

I. TRADITIONAL SEARCH		
1. DIALOG databases searched		
File 155: MEDLINE(R) 1966-2000 File 73: EMBASE 1974-2000 File 5: Biosis Previews(R) 1969-2000 File 434: SciSearch(R) Cited Ref Sci 1974-1989 File 91: MANTIS(TM) 1880-2000 File 164: Allied & Alternative Medicine(AMED) 1984-1999 File 48: SPORTDiscus 1962-1999 File 149: TGG Health&Wellness DB(SM) 1976-2000 File 162: CAB HEALTH 1983-2000 File 151: HealthSTAR 1975-1999 File 77: CONFERENCE PAPERS INDEX 1973-2000 File 71: ELSEVIER BIOBASE 1994-2000		
2. DIALOG search strategy		
<p>?s (electromagnetics or (magnetic or electromagnetic or electrical)(2n)(field or fields or therapy or therapies or stimulation or treatment? or energy))/ti,de</p> <p>?s (pulse or pulsed or pulsing)</p> <p>?s s1 and s2</p> <p>?s (pulse? (w)signal(w)therapy)</p> <p>?s s3 or s4</p> <p>?s (musculoskeletal or soft(w)tissue or tendin? or tendon? or orthop? or osteo? or arthriti? or bursitis or inflammation or fibromyalgia)/ti,de</p> <p>?s (myalgia or cartilage or menisci or mensicus or chondrol? or chondral? or shoulder? or elbow? or knee or knees or spine or vertebrae or lumbar or spinal)/ti,de</p> <p>?s (sacroiliac or sacrum or wrist? or ankle? or hip or hips or temporomandibular or joint or joints or ligament? or epicondylitis or rotator(w)cuff or sprain? or strain? or headache? or chronic(2w)pain)/ti,de</p> <p>?s s6 or s7 or s8</p> <p>?s s5 and s9</p> <p>?s ((random? or control? or clinical or blind or blinded or mask or masked)(2w)(trial or trials or study or studies or method))</p> <p>?s (cohort or cohorts or case(w)control or meta(w)analysis or metaanalysis or matched(w)pair or multivariate(w)analysis or random(w)allocation or technology(w)assessment or evidence(w)based or expert(w)panel)</p> <p>?s ((systematic or critical)(w)(appraisal or review) or (retrospective or prospective)(w)(study or studies or trial or trials))</p> <p>?s (multicent? or multi(w)cent? or cross(w)over or comparative(w)sampling or (comparison(w)group or research)(w)(design))</p> <p>?s s10 and (s11 or s12 or s13 or s14)</p> <p>?s s15/1980:2000</p> <p>?rd s16</p>	<p>?t s17/ti/1-126</p> <p>?s au=trock dh</p> <p>?s au=trock, dh</p> <p>?s au=trock d?</p> <p>?s au=trock, d?</p> <p>?s s10 and (s18 or s20 or s21)</p> <p>?rd s22</p> <p>?t s23/ti/1-3</p> <p>?s au=hershler, c?</p> <p>?s au=hershler c?</p> <p>?s au=markoll, r?</p> <p>?s au=markoll r?</p> <p>?s s10 and (s26 or s27)</p> <p>?rd s28</p> <p>?t s29/ti/1-3</p> <p>?s au=kornhauser, s?</p> <p>?s au=kornhauser s?</p> <p>?s s10 and (s30 or s31)</p> <p>?s au=binder, a?</p> <p>?s au=binder a?</p> <p>?s s10 and (s33 or s34)</p> <p>?rd s35</p> <p>?t s36/ti/1</p> <p>?s au=zizic, t?</p> <p>?s au=zizic t?</p> <p>?s s10 and (s37 or s38)</p> <p>?rd s39</p> <p>?t s40/ti/1-4</p> <p>?s au=moftett, j?</p> <p>?s au=moftett j?</p> <p>?s au=moftett, k?</p> <p>?s au=moftett k?</p> <p>?s s10 and (s41 or s42 or s43 or s44)</p>	
Note	<p>? = Dialog prompt</p> <p>rd = remove duplicates command</p>	<p>s = search command</p> <p>au = author field</p> <p>t = type command</p> <p>ca = cited author</p>

(Appendix C – continued)

II. FUGITIVE SEARCH	
1. In-house database searched	5. Internet peer-reviewed sites
<ul style="list-style-type: none"> In-House Catalog 	<ul style="list-style-type: none"> OMNI (Organising Medical Networked Information) Medweb Public Health
2. Directories	6. Internet search engines
<ul style="list-style-type: none"> ECRI. HealthCare Standards 	<ul style="list-style-type: none"> Google Northern Lights Altavista Adobe PDF Search
3. Commercial databases searched	7. Organizations contacted
<ul style="list-style-type: none"> Cochrane Library HSTAT (technology assessment guidelines) HSRProj (NLM) Dissertation Abstracts HTA Database National Research Register TRIP database (evidence-based medicine) Ebsco Academic Search Ebsco Canadian MAS 	<ul style="list-style-type: none"> Agence d'Evaluation des Technologies et des Modes d'Intervention en Santé (AÉTMIS) Agency for Health Care & Policy Research (AHCPR) Certified Pulsed Signal Therapy Centers Department of Clinical Measurement, Royal National Hospital for Rheumatic Diseases Johns Hopkins University US National Institutes of Health
4. Web library catalogues	
(searched using Library of Congress or National Library of Medicine (MeSH) subject headings)	
<ul style="list-style-type: none"> AMICUS - National Library of Canada library catalog Canadian Institute of Scientific and Technical Information (CISTI) library catalog WorldCat 	

APPENDIX D: **BCOHTA intervention study appraisal form**

 BC OFFICE OF HEALTH TECHNOLOGY ASSESSMENT Centre for Health Services and Policy Research University of British Columbia 429 – 2194 Health Sciences Mall Vancouver BC (Canada) V6T 1Z3 (604) 822-4810 bcohta@chspr.ubc.ca		
INTERVENTION STUDY APPRAISAL FORM		
Reference	Assessment	
	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Fair <input type="checkbox"/> Poor	
WHY?	HOW?	WHO?
<input type="checkbox"/> Is sufficient evidence presented to justify the study?	STUDY DESIGN <input type="checkbox"/> controlled trial <input type="checkbox"/> prospective analytic study <input type="checkbox"/> retrospective analytic study <input type="checkbox"/> before-after study <input type="checkbox"/> cross-sectional study <input type="checkbox"/> case series	<input type="checkbox"/> Is the population from which the sample is drawn CLEARLY described?
<input type="checkbox"/> Is there a CLEAR statement of the purpose of the study?		<input type="checkbox"/> Are inclusion and exclusion criteria specified and replicable?
<input type="checkbox"/> Is there a CLEAR statement of the study hypothesis?		<input type="checkbox"/> Do the inclusion and exclusion criteria match the goals of the study?
<input type="checkbox"/> Is it clearly outlined whether the study is considering: EFFICACY <i>or</i> EFFECTIVENESS?		<input type="checkbox"/> Do the authors account for every patient who is eligible for the study but does NOT enter it?
COMMENTS	<input type="checkbox"/> If it is a controlled trial, is the allocation of subjects TRULY randomized?	<input type="checkbox"/> Is the baseline comparability of the treatment and control groups documented?
	BLINDNESS	COMMENTS
	<input type="checkbox"/> unblinded <input type="checkbox"/> double-blind <input type="checkbox"/> single-blind <input type="checkbox"/> triple-blind	
	<input type="checkbox"/> Was prognostic stratification used?	
	COMMENTS	

WHAT?	HOW MANY?	SO WHAT?
What is the intervention? <input type="checkbox"/> Is it clearly defined and replicable?	<input type="checkbox"/> Was statistical significance considered?	<input type="checkbox"/> If differences were detected, were they clinically significant?
<input type="checkbox"/> Was compliance with intervention(s) measured and were non-compliers analyzed correctly?	<input type="checkbox"/> Were statistical tests applied appropriately?	<input type="checkbox"/> Were the patients entered and analyzed in the study sufficiently representative that the results can be generalized to other patients?
<input type="checkbox"/> Were CONTAMINATION and CO-INTERVENTION considered?	<input type="checkbox"/> How many tests of hypothesis (p-value) appear in the article?	<input type="checkbox"/> Was the intervention as performed by those in the study sufficiently representative that the results may be generalized to other settings?
<input type="checkbox"/> Were all patients who entered the study accounted for?	<input type="checkbox"/> Did the authors consider sample size requirements prior to the study?	<input type="checkbox"/> Were the outcomes assessed in the study sufficient to guarantee which of the therapies under study does the greatest good?
<input type="checkbox"/> Were withdrawals, drop-outs, cross-overs, and poor compliers analyzed in accordance with the aims of the study?	<input type="checkbox"/> When no differences were found, was there any consideration of possible β -error?	COMMENTS
<input type="checkbox"/> What outcome measures were utilized? Were all the relevant outcomes reported?	<input type="checkbox"/> Was the study large enough to detect important differences?	
COMMENTS	COMMENTS	

APPENDIX E: Excluded articles

Article *	Reason for exclusion
Aaron et al. (1989)	Osteonecrosis; not randomized
Barclay et al. (1983)	non-randomized controlled trial
Barker et al. (1985)	2 electrodes, not electromagnetic coil
Bassett et al. (1989)	not controlled
Bassett (1993)	traditional review
Butterfield (1998)	electrical stimulation
Canata et al. (1982)	case series
Casali & Pasquetti (1984)	case series
Cossu & Leuci (1999)	case series
Dikova (1989)	no blinding, randomization is not clear
Fisher & Kokoschinegg (1998)	outcome not described
Haimovici (1982)	case series
Harrison & Bassett (1984)	Legge-Perthes' disease; case series
Hershler & Sjaus (1999)	case series
Leclaire & Bourgouin (1991)	not pulsed
Low & Reed (1994)	electrotherapy text
Mooney (1990)	lumbar interbody fusions
Puett & Griffin (1994)	systematic review
Pujol et al. (1998)	detectable thermal effect
Sherman et al. (1998)	migraine
Sherman et al. (1999)	migraine
Vavreckova (1989)	case series
Wagner & Kobinger (1995)	case series
Wagstaff et al. (1986)	no blinding
Wilson (1974)	not randomized
Wright (1973)	case series, not PEME
Zizic et al. (1995)	not electromagnetic treatment

* Full citations are given in the **Bibliography**.

APPENDIX F: Technical specifications of devices in RCTs

Study	Name	Design	Pulse/Pause Duration	Frequency	Magnetic Field Strength	Power	Other
Binder ⁷ (1984)	PEMF	single ovoid coil consisting of 50 turns of copper wire covered by insulating tape	370 pulses / 4.23 microsecs.	pulse generation: 73±2 Hz			waveform parameters for each coil did not vary by more than 7%
Dal Conte ²⁵ (1986)	CMP (Italian) PMF	generated by an air dynamo of 60 cm diameter		50 Hz			33 Oe
Devereaux ²⁶ (1985)	PEMF	single coil 18 cms diameter consisting of 32 turns of 15 gauge copper wire	200 pulses/ microsecond	repetition rate: 15 Hz		13.5 mV (at center of coil)	
Foley-Nolan ²⁷ (1990)	PEMT	miniaturized, pulsed, short-wave diathermy generator incorporated in a soft collar	60 microsecs (450 pulses / second)	nominal frequency: 27MHz		source: 9V battery mean power of 1.5 mW/cm ² at the patient's surface	
Foley-Nolan ²⁸ (1992)	PEMT - pulsed electro-magnetic therapy	a soft collar into which a flexible miniaturized short wave diathermy generator was incorporated	60 microsecs (450 pulses / second)	nominal frequency: 27MHz		mean power of 1.5 milliWatts/cm ² at the patient's surface	
Menkes et al ²³ (1998)	PST		1 pulse / 0.1 second	2 - 60 Hz	<20 gauss	source: 120 V output: <2A	
Klaber Moffett ²⁹ (1996)	PSW - Pulsed Short Wave		82 pulses / second			mean = 23 Watts	

Study	Name	Design	Pulse/Pause Duration	Frequency	Magnetic Field Strength	Power	Other
(1996)	Short Wave		second				
Pennington ³⁰ (1993)	Diapulse						no parameters described
Trock ¹⁰ (1993)	PEMF		67 pulses / 0.1 milliseccs. (including 15 micropulses)	< 30 Hz (wave duration varied according to the frequency used)	10-20 gauss	source: 120 V coil current: ≤ 2 A	
Trock ² (1994)	PEMF		"the number of pulses/burst is determined by the frequency; the maximum was 20"	10 min: 5 Hz 10 min: 10 Hz 10 min: 12 Hz	10-25 gauss	source: 120 V coil current: < 2 A	"The wave form was quasirectangular with abruptly rising and deteriorating waveform; pulse burst duty cycle of up to 0.8"
Van Steenbrugge ³¹ (1988)	OMP (French)			initially at a low frequency (26 Hz) during at least the 5 first sessions and increased to the frequency of 200Hz			27 mH (short waves), of 1KW of power, with trains of emission of 400 microsecs
Wilson ⁵ (1972)	Diapulse		65 pulses / 1,600 microsecond (at 27.12 megacycles)			975 watt emission	

APPENDIX G: Randomized controlled trials of non-PST PEME devices

Study	Device	Disorder	Outcome	Sample	Treatment Effect
Binder ⁷ (1984)	PEMF	persistent rotator cuff tendonitis	pain & range of movement	29	Improvement in mean pain score, painful arc, pain on resisted movement, and active range was greater in treated vs. control at both 2 and 4 weeks.
Dal Conte ²⁵ (1990)	Italian=CMP; translation=PMF or sinusoidal PMF	symptomatic unilateral calcified periarthrosis of the shoulder	pain & arm motion	60	There was significant improvement in the treatment group in spontaneous pain, induced pain and range of motion and no significant improvement in the control group.
Devereaux ²⁶ (1985)	PEMF	chronic lateral humeral epicondylitis	pain & daily living scale	30	There were no significant differences, for all assessments, between the active and inactive groups except at six weeks: grip strength in extensions (p<0.05) and in flexion (p<0.05).
Foley-Nolan ²⁷ (1990)	PEMT - pulsed electromagnetic therapy	persistent neck pain	pain & neck movement	20	Treatment group had significant change from baseline in pain (p<0.005) and motion (p< 0.008); placebo did not (change in 10 point VAS of 3 vs. 1.25 and change in range of motion 0.5/6.0 vs 0.15/6.0).
Foley-Nolan ²⁸ (1992)	PEMT - pulsed electromagnetic therapy	acute whiplash injuries	pain & range of neck movement	40	At 2 weeks (VAS T=3.75/10 vs. C=6.00/10;p<0.05) and 4 weeks (2.5 vs. 5.00; p< 0.05) the treatment group had significantly less pain than the control group - no difference at 12 weeks. At 12 weeks the treatment group had slightly higher range of motion (4.5/6 vs. 4/6; p< 0.05).
Klaber Moffett ²⁹ (1996)	PSW - Pulsed Short Wave	osteoarthritis of the hip or knee	pain & general health scale	75	There were no SS differences in improvement in pain or general health between the T and C groups.

Study	Device	Disorder	Outcome	Sample	Treatment Effect
Pennington ³⁰ (1993)	Diapulse	ankle sprain	edema	50	The mean change in ankle volume (cubic centimeters of water displaced) was greater in the Tx group (44 vs. 11; p<0.01). The percent decrease in ankle volume was 4.7% for treatment group vs. 0.95% in placebo group (p<0.01).
Trock ¹⁰ (1993)	PEMF	osteoarthritis	pain & ADL	27	In the treatment group significant improvement was found in all measures of pain and ADL, no statistically significant improvement was found in the placebo group. The treated group averaged 36% improvement in the mean value for each variable evaluated at the end of treatment; the placebo group averaged 10%.
Trock ² (1994)	PEMF	osteoarthritis of either knee or cervical spine	pain & ADL	167	At the end of treatment, the mean level of improvement from baseline was always higher for the treated patients than the placebo group. The difference was statistically significant for pain (27.21 vs. 14.03; p=0.005), pain on passive motion (0.70 vs. 0.41; P=0.045), but not ADL difficulty and joint tenderness. One month following treatment statistically significant differences were found in pain (24.77 vs. 11.86; P=0.018), pain on passive motion (0.78 vs. 0.16; p<0.0001), and joint tenderness (0.73 vs. 0.21; p=0.001).
Van Steenbrughe ³¹ (1988)	OMP (French)	osteopathic or tendinitis conditions	pain & other treatment sought	141	A significant difference was found between the % of patients with improvement in neck pain in the treatment and control group (70% vs. 29%; p<0.01). There was no difference in lower back, knee, shoulder or other pain.
Wilson ⁵ (1972)	Diapulse	inversion injury of the ankle	swelling, pain & disability	40	Percentage improvement in treated patients was “about twice” that of the placebo patients.

BIBLIOGRAPHY

- Aaron RK, Lennox D, Bunce GE, Ebert T. The conservative treatment of osteonecrosis of the femoral head: a comparison of core decompression and pulsing electromagnetic fields. *Clin Orthop* 1989;249:209-18.
- Agence d'évaluation des technologies et des modes d'intervention en santé (AETMIS), Framarin A. *Thérapie du signal pulse et traitement de l'ostéoartrite*. AETMIS 01-2 RF. Montreal (QC): Agence d'Évaluation des Technologies et des Modes d'Intervention en Santé, 2001.
- The Alternative Therapy Evaluation Committee (ICBC). *Pulsed signal therapy: a review of the scientific evidence*. Vancouver (BC): The Alternative Therapy Evaluation Committee, Insurance Corporation of British Columbia; 1999.
- American College of Rheumatology Ad Hoc Committee on Clinical Guidelines. Guidelines for the initial evaluation of the adult patient with acute musculoskeletal symptoms. *Arthritis & Rheumatism* 2000;39(1):1-8.
- American College of Rheumatology Subcommittee on Osteoarthritis Guidelines. Recommendations for the medical management of osteoarthritis of the hip and knee: 2000 update. *Arthritis & Rheumatism* 2000;43(9):1905-15.
- Barclay V, Collier RJ, Jones A. Treatment of various hand injuries by pulsed electromagnetic energy (Diapulse). *Physiotherapy* 1983;69(6):186-8.
- Barker AT, Barlow PS, Porter J, Smith ME, Clifton S, Andrews L, O'Dowd WJ. A double-blind clinical trial of low power pulsed shortwave therapy in the treatment of a soft tissue injury. *Physiotherapy* 1985;71:500-4.
- Bassett CAL. Beneficial effects of electromagnetic fields. *J Cell Biochem* 1993;51(4): 387-93.
- Bassett CAL, Schink-Ascani M, Lewis SM. Effects of pulsed electromagnetic fields on Steinberg ratings of femoral head osteonecrosis. *Clin Orthop* 1989;246:172-85.
- Bentall R. Healing by electromagnetism - fact or fiction. *New Scientist* April 22 1976:166-67.
- Binder A, Parr G, Hazleman B, Fitton-Jackson S. Pulsed electromagnetic field therapy of persistent rotator cuff tendinitis: a double-blind controlled assessment. *Lancet* 1984 Mar 31;1 (8379):695-8.
- Butterfield DL. The effects of high-volt pulsed current electrical stimulation on delayed onset muscle soreness. M.S. Provo (UT): Brigham Young University; 1996.
- Canata P, Frieri G, Pugliese M, Empoli M, Dallera A. Use of pulsating electromagnetic fields in (traumatic) sports injuries. *Medicina dello Sport* 1982;35(1):11-13.
- Casali R, Pasquetti P. Efficacia antalgica della elettromagnetoterapia pulsata ad alta frequenza. *Clin Europ* 1984;4-5-6:540-6.
- Center for Devices and Radiological Health. Center for Devices and Radiological Health (CDRH) Freedom of Information (FOI) releasable establishment registration and device listing files. Available from: URL: <http://www.fda.gov/cdrh/comp/estregls.html>.

Center for Devices and Radiological Health. Getting to market with a medical device. Available from: URL: <http://www.fda.gov/cdrh/devadvice/3122.html>.

Certified Pulse Signal Therapy Centers. Conditions PST Can Treat. Available from: URL: <http://www.certifiedpst.com/conditions.html>.

Certified Pulse Signal Therapy Centers. Frequently asked questions about PST. Available from: URL: <http://www.certifiedpst.com/faq.html>.

Certified Pulse Signal Therapy Centers. International PST Centers. Available from: URL: <http://www.certifiedpst.com/international.html>.

Certified Pulse Signal Therapy Centers. PST San Diego (Tijuana, Mexico). Available from: URL: <http://www.certifiedpst.com/sandiego.html>.

Certified Pulse Signal Therapy Centers. Research overview. Available from: URL: <http://www.certifiedpst.com/studies.html>.

CIBA Pharmaceutical Company. Physical factors in bone remodeling. The CIBA collection of medical illustrations. [West Caldwell (NJ)]: [CIBA Pharmaceutical Company]; [199?].

Clinical trials: research summary conducted at the Magnetic Therapy Center Waterbury, Connecticut. [Boca Raton (FL)]: [Biomagnetic Therapy Systems, Inc.], [Unpublished material submitted by manufacturer to WCB in support of funding application].

Comparison with magnetic field therapy. [Boca Raton (FL)]: [Biomagnetic Therapy Systems, Inc.]; [Unpublished material submitted by manufacturer to WCB in support of funding application].

Comprehensive report of all patients treated with magnetic therapy in Waterbury, Connecticut. [Boca Raton (FL)]: [Biomagnetic Therapy Systems, Inc.]; [Unpublished material submitted by manufacturer to WCB in support of funding application].

Cossu M, Leuci C. Long-term results achieved by pulsed signal therapy (PST). *La Riabilitazione* 1999;32(1):11-15.

Dal Conte G, Rivolini P, Combi F. Treatment of calcified periartthritis of the shoulder with pulsating magnetic fields: a controlled study. *La Riabilitazione* 1990;23(1):27-33.

Devereaux MD, Hazleman BL, Thomas PP. Chronic lateral humeral epicondylitis: a double-blind controlled assessment of pulsed electromagnetic field therapy. *Clin Exp Rheumat* 1985 Oct-Dec;3(4):333-6.

Dikova R. Therapeutic potentialities of low-frequency pulsed magnetic field in medical rehabilitation of rheumatoid spondylarthritis patients. *Kurortologiya I Fizioterapiya* 1989;26(4):12-17.

Faensen M. Pulsed signal therapy: range of application and active principles. [Boca Raton (FL)]: [Biomagnetic Therapy Systems, Inc.]; [Unpublished material submitted by manufacturer to WCB in support of funding application].

Fisher G, Kokoschinegg P. Effects of low-intensity, pulsed magnetic fields on humans: basic research on humans and animals. Graz (Austria): The Hygiene Institute of the University of Graz; [1998].

Foley-Nolan D, Barry C, Coughlan RJ, O'Connor P, Roden D. Pulsed high frequency (27MHz) electromagnetic therapy for persistent neck pain: a double-blind, placebo-controlled study of 20 patients. *Orthopedics* 1990 13(4):445-51.

Foley-Nolan D, Moore K, Codd M, Barry C, O'Connor P, Coughlan RJ. Low energy high frequency pulsed electromagnetic therapy for acute whiplash injuries: a double blind randomized controlled study. *Scand J Rehabil Med* 1992;24(1):51-9.

Haimovici N. The low-frequent pulsed magnetic field therapy in the treatment of degenerative joint illness. *Akt Rheumatol* 1982;7:81-4.

Harrison MHM, Bassett CAL. Use of pulsed electromagnetic fields in Perthes Disease: report of a pilot study. *J Pediatr Orthop* 1984;4:579-84.

Health Canada. Medical devices regulations. Ottawa (ON): Health Canada, 1998.

Hershler C, Sjaus A. Pulsed signal therapy: treatment of chronic pain due to traumatic soft tissue injury. *Int Med J* 1999;6(3):167-73.

Hochberg MC, Altman RD, Brandt KD, Clark BM, Dieppe PA, Griffin MR, Moskowitz RW, Schnitzer TJ. Guidelines for the medical management of osteoarthritis: Part I. Osteoarthritis of the Hip. *Arthritis & Rheumatism* 2000;38(11):1535-40.

Hochberg MC, Altman RD, Brandt KD, Clark BM, Dieppe PA, Griffin MR, Moskowitz RW, Schnitzer TJ. Guidelines for the medical management of osteoarthritis: Part II. Osteoarthritis of the Knee. *Arthritis & Rheumatism* 2000;38(11):1541-6.

Klaber Moffett JA, Richardson PH, Frost H, Osborn A. A placebo controlled double blind trial to evaluate the effectiveness of pulsed short-wave therapy for osteoarthritic hip and knee pain. *Pain* 1996;67(1):121-7.

Leclaire R, Bourgooin J. Electromagnetic treatment of shoulder periarthritis: a randomized controlled trial of the efficiency and tolerance of magnetotherapy. *Arch of Phys Med Rehabil* 1991 Apr;72(5):284-7.

Low J, Reed A. Electromagnetic fields: shortwave diathermy, pulsed electromagnetic energy and magnetic therapies. In: Low J, Reed A. *Electrotherapy explained: principles and practice*. 2nd ed. Boston (MA): Butterworth-Heinemann; 1994. p. 239-278.

Markoll R. Comparison of PST to other treatment modalities. [Boca Raton (FL)]: [Biomagnetic Therapy Systems, Inc.]; [Unpublished material submitted by manufacturer to WCB in support of funding application].

Menkes CJ, Perrot S, Lompre J-L, Beffy J-L, Marty M. Study to verify the analgesic effectiveness of pulsed signal therapy (PST) in gonarthrosis: clinical and statistical report. 2nd. Boca Raton (FL): Bio-Magnetic Therapy Systems Inc; 1998.

Mooney V. A Randomized double-blind prospective study of the efficacy of pulsed electromagnetic fields for interbody lumbar fusions. *Spine* 1990;15(7):708-12.

New medical applications: pilot studies completed. [Boca Raton (FL)]: [Biomagnetic Therapy Systems, Inc.]; [Unpublished material submitted by manufacturer to WCB in support of funding application].

Ogilivie-Harris DJ, Gilbert M. Treatment modalities for soft tissue injuries of the ankle: a critical review. *Clin J Sport Med* 1995;5:175-86.

Pennington GM, Danley DL, Sumko MH, Bucknell A, Nelson JH. Pulsed, non-thermal, high-frequency electromagnetic energy (DIAPULSE) in the treatment of grade I and grade II ankle sprains. *Mil Med* 1993 Feb;158(2):101-4.

Perrot S, Marty M, Kahan A, Menkes C-J. Efficacy of pulsed electromagnetic therapy in painful knee osteoarthritis. In: *Proceedings of the 62nd Annual Meeting of the American College of Rheumatology*, San Diego, 1998, p S357.

Postulates concerning possible mechanisms of action of pulsed electromagnetic field therapy of osteoarthritis. Boca Raton (FL): Biomagnetic Therapy Systems, Inc.; [Unpublished material submitted by manufacturer to WCB in support of funding application].

Puett DW, Griffin MR. Published trials of nonmedicinal and noninvasive therapies for hip and knee osteoarthritis. *Ann Intern Med* 1994; 121(2):133-40.

Pujol J, Pascual-Leone A, Dolz C, Delgado E, Dolz JL, Aldoma J. The effect of repetitive magnetic stimulation on localized musculoskeletal pain. *NeuroReports* 1998;9(8):1745-8.

Pulsed electromagnetic fields influence hyaline cartilage extracellular matrix composition without affecting molecular structure. *Osteoarthritis and Cartilage* 1996;4:63-6.

Pulsed signal therapy: the viable alternative. Munchen, Germany: Bio Magnetic Therapy Systems, Inc.; [Unpublished material submitted by manufacturer to WCB in support of funding application].

Ramey DW. Magnetic and electromagnetic therapy. *Sci Rev Altern Med* 1998;2(1):13-19.

Sackett DL. *Clinical epidemiology: a basic science for clinical medicine*. 2nd ed. Boston (MA): Little, Brown; 1991.

Schechter MT, LeBlanc FE. Critical appraisal of published research. In: Hanstroidl W, Spitzer O, McPeck B, Mulder DS, McKneally MF, editors. *Principles and practice of research: strategies for surgical investigators*. New York: Springer-Verlag; 1986. p. 112-7.

Sherman RA, Acosta NM, Robson L. Treatment of migraine with pulsing electromagnetic fields: a double-blind, placebo-controlled study. *Headache* 1999;39:567-75.

Sherman RA, Robson L, Marden LA. Initial exploration of pulsing electromagnetic fields for treatment of migraine. *Headache* 1998;38:208-13.

Trock DH. Electromagnetic fields and magnets : investigational treatment for musculoskeletal disorders. *Rheum Dis Clin North Am* 2000;26(1):51-62.

Trock DH, Bollet AJ, Dyer RH Jr, Fielding LP, Miner WK, Markoll R. A double-blind trial of the clinical effects of pulsed electromagnetic fields in osteoarthritis. *J Rheumatol* 1993 Mar;20 (3):456-60.

Trock DH, Bollet AJ, Markoll R. The effect of pulsed electromagnetic fields in the treatment of osteoarthritis of the knee and cervical spine: report of randomized, double blind, placebo controlled trials. *J Rheumatol* 1994 Oct;21(10):1903-11.

- Van Steenbrugge G, Panthier G, Maigne JY, Maigne R. Pulsed magnetic short waves for pain therapy. *Annales de Readaptation et de Medecine Physique* 1988;31(2):227-32.
- Vavreckova M. Our experiences with magnetotherapy. *Fysiat Vestn* 1989;67(2):88-91.
- Wagner W, Kobinger W, Fischer G. Relieving pain in diseases of the musculoskeletal system with small apparatuses that produce magnetic fields. *Artzt & Praxis* 1995;49(728):1-6.
- Wagstaff P, Wagstaff S, Downey M. A pilot study to compare the efficacy of continuous and pulsed magnetic energy [short-wave diathermy] on the relief of low back pain. *Physiotherapy* 1986;72(11):563-6.
- Wilson DH. Comparison of short wave diathermy and pulsed electromagnetic energy in treatment of soft tissue injuries. *Physiotherapy* 1974;60(10):309-10 .
- Wilson DH. Treatment of soft-tissue injuries by pulsed electrical energy. *Br Med J* 1972 Apr 29;2(808):269-70.
- Wright GG. Treatment of soft-tissue and ligamentous injuries in professional footballers. *Physiotherapy* 1973;59(12):385-7.
- Wurstbauer C. Goodbye to pain. *Die Apotheke* [Unpublished material submitted by manufacturer to WCB in support of funding application].
- Zizic TM, Hoffman KC, Holt PA, Hungerford DS, O'Dell JR, Jacobs MA, Lewis CG, Deal CL, Caldwell JR, Cholewczynski JG, Free SM. The treatment of osteoarthritis of the knee with pulsed electrical stimulation. *J Rheumatol* 1995;22:1757-61.

REFERENCES

1. Frequently asked questions about PST. Available from: URL: <http://www.certifiedpst.com/faq.html>.
2. Trock DH, Bollet AJ, Markoll R. The effect of pulsed electromagnetic fields in the treatment of osteoarthritis of the knee and cervical spine: report of randomized, double blind, placebo controlled trials. *J Rheumatol* 1994 Oct;21(10):1903-11.
3. Kirby K. Explanation of electromagnetic properties of Pulsed Signal Therapy. Vancouver (BC): Workers' Compensation Board of BC; 2000. Personal communication.
4. Low J, Reed A. Electromagnetic fields: shortwave diathermy, pulsed electromagnetic energy and magnetic therapies. In: Low J, Reed A. *Electrotherapy explained: principles and practice*. 2nd ed. Boston (MA): Butterworth-Heinemann; 1994. p. 239-278.
5. Wilson DH. Treatment of soft-tissue injuries by pulsed electrical energy. *Br Med J* 1972 Apr 29;2(808):269-70.
6. Hershler C, Sjaus A. Pulsed signal therapy: treatment of chronic pain due to traumatic soft tissue injury. *Int Med J* 1999;6(3):167-73.
7. Binder A, Parr G, Hazleman B, Fitton-Jackson S. Pulsed electromagnetic field therapy of persistent rotator cuff tendinitis: A double-blind controlled assessment. *Lancet* 1984 Mar 31;1(8379):695-8.
8. Wilson DH. Comparison of short wave diathermy and pulsed electromagnetic energy in treatment of soft tissue injuries. *Physiotherapy* 1974;60(10):309-10.
9. Bassett CAL. Beneficial effects of electromagnetic fields. *J Cell Biochem* 1993;51(4): 387-93.
10. Trock DH, Bollet AJ, Dyer RH Jr, Fielding LP, Miner WK, Markoll R. A double-blind trial of the clinical effects of pulsed electromagnetic fields in osteoarthritis. *J Rheumatol* 1993 Mar;20(3):456-60.
11. Bassett CAL, Schink-Ascani M, Lewis SM. Effects of pulsed electromagnetic fields on Steinberg ratings of femoral head osteonecrosis. *Clin Orthop* 1989;246:172-85.
12. Aaron RK, Lennox D, Bunce GE, Ebert T. The conservative treatment of osteonecrosis of the femoral head: a comparison of core decompression and pulsing electromagnetic fields. *Clin Orthop* 1989;249:209-18.
13. Harrison MHM, Bassett CAL. Use of pulsed electromagnetic fields in Perthes Disease: report of a pilot study. *J Pediatr Orthop* 1984;4:579-84.
14. Certified Pulse Signal Therapy Centers. International PST Centers. Available from: URL: <http://www.certifiedpst.com/international.html>.

15. Health Canada. Medical devices regulations. Ottawa (ON): Health Canada; 1998.
16. Certified Pulse Signal Therapy Centers. PST San Diego (Tijuana, Mexico). Available from: URL: <http://www.certifiedpst.com/sandiego.html>.
17. Center for Devices and Radiological Health. Getting to market with a medical device. Available from: URL: <http://www.fda.gov/cdrh/devadvice/3122.html>.
18. Center for Devices and Radiological Health. Center for Devices and Radiological Health (CDRH) Freedom of Information (FOI) releasable establishment registration and device listing files. Available from: URL: <http://www.fda.gov/cdrh/comp/estregls.html>.
19. Comparison with magnetic field therapy. [Boca Raton (FL)]: [Biomagnetic Therapy Systems, Inc.]; [Unpublished material submitted by manufacturer to WCB in support of funding application].
20. Conditions PST Can Treat. Available from: URL: <http://www.certifiedpst.com/conditions.html>
21. Sackett DL. Clinical epidemiology: a basic science for clinical medicine. 2nd ed. Boston (MA): Little, Brown, 1991.
22. Schechter MT, LeBlanc FE. Critical appraisal of published research. In: Hanstroidl W, Spitzer O, McPeck B, Mulder DS, McKneally MF, editors. Principles and practice of research: strategies for surgical investigators. New York: Springer-Verlag; 1986. p. 112-7.
23. Menkes CJ, Perrot S, Lompre J-L, Befy J-L, Marty M. Study to verify the analgesic effectiveness of pulsed signal therapy (PST) in gonarthrosis: clinical and statistical report. 2nd ed. Boca Raton (FL): Bio-Magnetic Therapy Systems Inc; 1998.
24. Certified Pulse Signal Therapy Centers. Research overview. Available from: URL: <http://www.certifiedpst.com/studies.html>.
25. Dal Conte G, Rivolini P, Combi F. Treatment of calcified periarthritis of the shoulder with pulsating magnetic fields: a controlled study. *La Riabilitazione* 1990;23(1):27-33.
26. Devereaux MD, Hazleman BL, Thomas PP. Chronic lateral humeral epicondylitis--a double-blind controlled assessment of pulsed electromagnetic field therapy. *Clin Exp Rheumat* 1985 Oct-Dec;3 (4):333-6.
27. Foley-Nolan D, Barry C, Coughlan RJ, O'Connor P, Roden D. Pulsed high frequency (27MHz) electromagnetic therapy for persistent neck pain: a double-blind, placebo-controlled study of 20 patients. *Orthopedics* 1990 13(4):445-5.
28. Foley-Nolan D, Moore K, Codd M, Barry C, O'Connor P, Coughlan RJ. Low energy high frequency pulsed electromagnetic therapy for acute whiplash injuries: a double blind randomized controlled study. *Scand J Rehabil Med* 1992;24(1):51-9.
29. Klaber Moffett JA, Richardson PH, Frost H, Osborn A. A placebo controlled double blind trial to evaluate the effectiveness of pulsed short-wave therapy for osteoarthritic hip and knee pain. *Pain* 1996;67(1):121-7.

30. Pennington GM, Danley DL, Sumko MH, Bucknell A, Nelson JH. Pulsed, non-thermal, high-frequency electromagnetic energy (DIAPULSE) in the treatment of grade I and grade II ankle sprains. *Mil Med* 1993 Feb;158(2):101-4.
31. Van Steenbrugghe G, Panthier G, Maigne JY, Maigne R. Pulsed magnetic short waves for pain therapy. *Annales de Readaptation et de Medecine Physique* 1988;31(2):227-32.