Radiation Protection Dosimetry (2008), Vol. 128, No. 2, pp. 180–190
Advance Access publication 11 June 2007 doi:10.1093/rpd/ncm309

OCCUPATIONAL EXPOSURE TO ELECTROMAGNETIC FIELDS IN PHYSIOTHERAPY DEPARTMENTS

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Received December 15 2006, revised April 23 2007, accepted April 23 2007

To assess occupational exposure to electromagnetic fields, 11 microwave (MW), 4 short-wave diathermy and 15 magneto therapy devices were analysed in eight physiotherapy departments. Measurements taken at consoles and environmental mapping showed values above European Directive 2004/40/EC and ACGIH exposure limits at ~50 cm from MW applicators (2.45 GHz) and above the Directive magnetic field limit near the diathermy unit (27.12 MHz). Levels in front of MW therapy applicators decreased rapidly with distance and reduction in power; this may not always occur in work environments where nearby metal structures (chairs, couches, etc.) may reflect or perturb electromagnetic fields. Large differences in stray field intensities were found for various MW applicators. Measurements of power density strength around MW electrodes confirmed radiation fields between 30° and 150°, with a peak at 90°, in front of the cylindrical applicator and maximum values between 30° and 150° over the whole range of 180° for the rectangular parabolic applicator. Our results reveal that although most areas show substantially low levels of occupational exposure to electromagnetic fields in physiotherapy units, certain cases of over-occupational exposure limits do exist.

INTRODUCTION

In hospital and health clinics, occupational exposure to stray electromagnetic fields (EMF) may be associated with electromedical equipment employed for physiotherapy applications. The therapeutic effect of this type of equipment derives from the exploitation of heat produced by the absorption of electromagnetic energy in biological tissues for high-frequency fields, and from the influence of transmembrane ionic activity for low-frequency fields[1,2].

The most frequent therapeutic applications are for degenerative joint diseases. The devices used for these applications include: microwave (MW) equipment, which has a frequency of 2450 MHz; short-wave diathermy (SWD), mainly 27.12 MHz; and magneto therapy, operating at extremely low frequencies (ELF) (under 100 Hz).

Italian legislation[3] only protects the general population from electromagnetic fields, therefore, for occupational exposure, reference is made to Directive 2004/40/EC of the European Parliament on the minimum health and safety requirements regarding the exposure of workers to the risk arising from physical agents (electromagnetic fields)[4]. The Directive, which is based on International Commission on Non-Ionizing Radiation Protection (ICNIRP)[5] will apply in the countries of the European union and establishes exposure limit values and action values. Compliance with these limits will ensure that workers exposed to EMF are protected against all known adverse health effects. The action values are obtained from the exposure limit values according to the rationale used by the ICNIRP in its guidelines on limiting exposure to non-ionising radiation[5]. Practically, the action values are the directly measurable parameters and compliance with them will ensure compliance with the relevant exposure limit values. The Directive does not address suggested long-term effects.

The action values, according to frequency range are: MW therapy, 137 V m^{-1} electric field (***E***-field), 0.36 A m^{-1} magnetic field (***H***-field) and 50 W m^{-2} power density (*S*); SWD therapy 61 V m^{-1} ***E***-field and 0.16 A m^{-1} ***H***-field; magneto therapy (operating at a frequency of 50 Hz), 10 000 V m^{-1} ***E***-field and 500 μT magnetic induction (***B***-field).

The American Conference of Governmental Industrial Hygienists[6], specifies the following threshold limit values (TLVs): MW therapy, power density 81.6 W m^{-2}; SWD, ***E***-field 67.9 V m^{-1} and ***H***-field 0.6 A m^{-1}; and magneto therapy, ***E***-field 25 000 V m^{-1} and ***B***-field 1200 μT. The ACGIH also recommends that, in view of possible interference by electromagnetic fields at frequencies of 50/60 Hz, wearers of pace-makers or similar electronic devices should be exposed to levels under 1 kV m^{-1} and 100 μT.

The question of the possible risk of cancer by exposure to electromagnetic fields, especially ELF, became a concern to scientists and is now an important public debate. In June 2001, the International Agency for Research on Cancer (IARC) classified ELF fields as possibly carcinogenic to humans

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(group 2B), based on the consistent statistical associations between high levels of residential magnetic fields ($f = 50–60$ Hz) and the double risk of childhood leukaemia[7]. However, children exposed to ELF magnetic fields $<0.4\ \mu$T have no increased risk for leukaemia[8]. Instead, no evidence has been found that residential or occupational exposure of adults to ELF electromagnetic fields increased risk for any kind of cancer[7,9].

The aim of our study is to assess exposure to electromagnetic fields of healthcare personnel using physiotherapy equipment, in order to demonstrate what areas provide a greater risk of exposure and to determine the influence of patient localisation and nearby obstacles in the mapping of field intensities. The emission characteristics of various types of applicators for MW therapy and the behaviour of the field intensity, according to distance and power emitted, were also evaluated.

METHODS

Eight physiotherapy departments, in seven hospitals in Padua and its surrounding province in North East Italy, were examined by monitoring 11 MW, 4 SWD and 15 magneto therapy units, including 12 portable devices with local applicators and 3 couches with solenoids. Measurements were conducted behind the consoles, where operators remain while programming equipment under normal operating conditions; in two departments, several room maps were made showing the strengths of stray fields with the physiotherapist and patients in different positions and locations for each map.

The rooms varied in size and were subdivided into cubicles by curtains or wood and plastic panels. In each of these cubicles, one particular (physical or manual) therapy was carried out and the operator moved around continually to check on patients. Physiotherapists treating patients in one cubicle would sometimes be within 1 m of the electrodes in an adjacent cubicle during a normal work-shift. Each operator worked a daily shift of 6 h.

Different field strengths were measured with a digital field measurement device (model 8053, PMM, Segrate, MI, Italy), connected to specific isotropic probe detectors with different frequency range. Because these detectors are sensitive to metal infrastructures and other conducting bodies, the field technician remained at a distance of 5 m while performing measurements. The calibration procedure of the instrument was performed according to the PMM internal procedure PTP 09–29. The expanded uncertainty of measurement was $\pm 10\%$ and the value expressed is 6-min root mean square.

The measurable action values are intended to be spatially averaged values over the entire body of the exposed individual, with the important proviso that the ICNIRP basic restrictions on localised exposure are not exceeded; they are accordingly based on the rate of energy absorption as measured by the specific absorption rate for high-frequencies and current density for low-frequency fields[4,5]. For compliance, averaging over the entire body is needed instead of separate data for eye, trunk and gonads. According to national guidelines[10], to estimate spatial average over the entire body, measurements of emissions were carried out at three heights above the ground: 110 cm (average height of gonads), 150 cm (trunk) and 170 cm (eyes), and the means of the three results were calculated for MW and SWD units; for magneto therapy, a single measurement was made between 100 and 150 cm from the floor. The international guide for occupational exposure to radiation[5] is based on an averaging time of 6 min but measuring field strengths averaged over a 6-min period would have greatly increased the time required for data collection. Therefore, as made by other authors[11], some tests were completed that compared measurements taken over a 6-min period with shorter duration intervals of data collection between 1 and 6 min and in all cases the samples did not differ significantly.

MW measurements

Characteristics of the equipment are reported in Table 1.

We used electric field probe PMM EP-330 (frequency range 100 kHz–3 GHz, level range 0.3–300 V m^{-1}) for E- and H-field because the physiotherapists were mostly working in the far field of equipment operating at 2.45 GHz (wavelength 0.12 m). In fact, in the far field region, the plane-wave model is a good approximation of the electromagnetic field propagation. The characteristics of a plane-wave are:

- wave fronts have a planar geometry;
- $\boldsymbol{E}$ and $\boldsymbol{H}$ vectors and the direction of propagation are mutually perpendicular;
- the phase of $\boldsymbol{E}$- and $\boldsymbol{H}$-fields is the same, and the quotient of the amplitude of $\boldsymbol{E}/\boldsymbol{H}$ is constant throughout the space. In free space, the ratio of their amplitudes $\boldsymbol{E}/\boldsymbol{H} = 377$ ohm, which is the characteristic impedance of free space;
- power density (S), the power per unit area normal to the direction of propagation is related to the electric and magnetic fields by the expression:

$$S = \boldsymbol{EH} = \boldsymbol{E}^2/377 = 377\ \boldsymbol{H}^2 \qquad (1)$$

All generators were operating in continuous mode.

In one department, measurements were carried out when two MW units were working at the same time.

Table 1. Characteristics of 11 MW devices.

No.	Manufacturer	Model	Treatment	Output power (W)
2	Roland	RX 250P.2	Neck	20
2	Roland	RX 250P.2	Back	150
1	Sanitas	MEGATHERM 250	Neck	60
3	Sanitas	MEGATHERM 200 N	Back	80
1	Biohelp		Back	60
1	Biohelp		Back	80
1	Cosmogamma		Back	110

Frequency 2450 MHz. Setting: continuous wave.

To evaluate the emission for different MW applicators, power density distributions ($W\,m^{-2}$) were mapped around two devices (one with cylindrical electrodes and one with parabolic applicators) at distances of 50, 100, 150 and 200 cm from the radiation source, both horizontally and vertically. Measurements were made in front of the applicator and in directions between 0° and 180°, in 30° steps, at heights of 110 cm (gonads), 150 cm (trunk) and 170 cm (eyes).

SWD measurements

Characteristics of the equipment are reported in Table 2.

We used electric field probe PMM EP-330 (frequency range 100 kHz–3 GHz, level range 0.3–300 $V\,m^{-1}$) for ***E***-field, and magnetic field PMM HP-032 (frequency range 0.1–30 MHz, level range 0.01–20 $A\,m^{-1}$). All generators were operating in continuous mode.

Magneto therapy measurements

Characteristics of the equipment are reported in Table 3.

We used electric–magnetic field analyser EHP - 50A (5 Hz–100 kHz, ***E***-field level range 0.1 $V\,m^{-1}$ – 100 $kV\,m^{-1}$, ***B***-field level range 10 nT–10 mT).

Table 2. Characteristics of four SWD equipments.

No.	Manufacturer	Model	Treatment	Output power (W)
3	ASMOT-ENRAF NONIUS	CURAPULS 419	Knee	125
1	Sanitas	THERMOSAN 2010	Shoulder	300

Frequency 27.12 MHz.

To evaluate the influence of the patient, ELF measurements were made with and without the patient on the couch.

RESULTS

MW equipment

Figure 1 shows the EMF values emitted by all MW therapy units, measured behind their consoles and Table 4 shows the ranges of EMF fields in the environmental maps for four MW units.

Measurements at a distance >1 m from the electrodes in environmental mapping and behind all MW consoles assessed fell below Directive action values and ACGIH TLVs; some overexposure is possible at ~50 cm from the applicator. In other locations (e.g. doorways, corridors, adjacent cubicles), our measurements on all types of equipment always showed values below the recommended exposure limits.

Figure 2 shows variations in power density emitted by a MW unit (Roland RX 250P) with distance from the electrodes set at various values at 150 cm from the floor.

Figures 3 and 4 show power density distribution (from 0° to 180° around electrodes) at 150 cm above the ground around two different MW electrode configurations, one cylindrical (Biohelp) and one parabolic (Biohelp). Data confirm, at the three heights above the ground, for cylindrical applicators, radiation between 30° and 150° with peak on the central axis at 90°, whereas the rectangular parabolic applicator shows distribution through 180°, with peaks between 30° and 150°.

SWD equipment

Figure 5 and Table 5 show the EMF values emitted by SWD devices, measured behind their consoles and from environmental maps, respectively.

E-field behind the consoles of SWD (Figure 5A) units fell below Directive action values and ACGIH

Table 3. Characteristics of 15 magneto therapy devices.

No.	Manufacturer	Model	Type	Treatment	Output magnetic field intensity (μT)
3	IGEA s.r.l.	Biostim	Portable	Shoulder	200
3	IGEA s.r.l.	Unix	Portable	Shoulder	200
2	Sanitas	THERODORE 27	Portable	Shoulder	300
2	Molinari R.	MDM 800	Portable	Knee	500
2	Bn Elettronica	Magneton CMP 100	Portable	Knee	500
2	Asa	Pmt 5 Pro	Solenoids	Back	510 and 600
1	Sanitas	Electric	Solenoids	Hip	1000

Frequency 50 Hz.

TLV, but the Directive action value for ***H***-field (Figure 5B) was exceeded in one case (0.256 A m^{-1}).

Environmental mapping showed values in other locations (e.g. doorways, corridors, adjacent cubicles) below the recommended exposure limits, which decreased with distance.

Magneto therapy

Figures 6 and 7 show the EMF values emitted, respectively, by fixed and portable magneto devices, measured behind their consoles.

Table 6 shows the ranges of ELF fields in the environmental maps for fixed magneto units and Table 7 shows the data of environmental mapping with and without the patient.

Magneto therapy ***E***- and ***B***-fields were all below the limits, behind the consoles and on the environmental map. The ***B***-field strengths at the consoles associated with fixed units were significantly greater than those with the portable units. Table 7 shows that ELF fields are less with the patient than without because the presence of the patient probably perturbs the field.

DISCUSSION

MW equipment

EMF measurements at a distance >1 m from the electrodes in environmental mapping and behind all the consoles of MW assessed fell below international occupational exposure limits[4, 6]. An overexposure is possible at ~50 cm from the applicator, a position where physiotherapists might work for few seconds to reassure a patient or to correct the position of the applicator towards the patient's body.

In agreement with Tzima and Martin[12] and Martin *et al.*[13], if operators stand at 1 m from 2.45 GHz (and 434 MHz) applicators during treatment and avoid standing in the vicinity of large metal objects that could reflect the MW radiation, they should not be exposed to fields above the reference level.

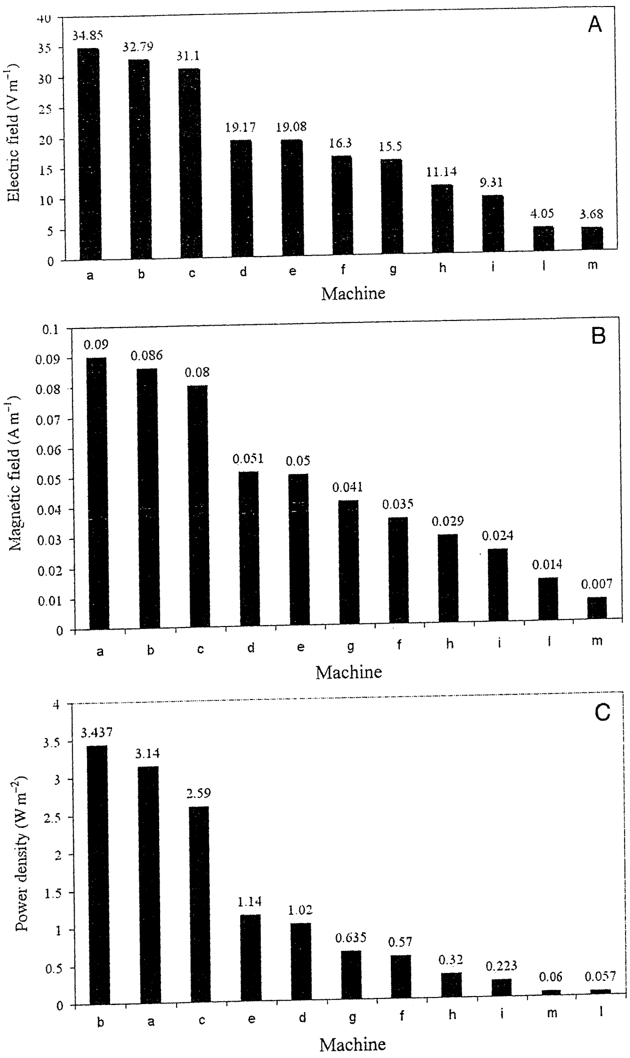
Martin *et al.*[14] reported that short exposures to fields 10–50 times the relative limits occurred near electrodes. A distance of at least 1 m from units during treatment is recommended for both operators and patients[12,13,15]. According to Casciardi *et al.*[16] and Grandi *et al.*[17], in MW therapy, ***E***-field intensities 200 V m^{-1} occur at 10 cm from the applicators.

In other sites, as reported in Table 4, our measurements on all types of equipment always showed values below the recommended limits. Even the simultaneous use of two MW units did not exceed the limits. Other authors[16] have measured ***E***-field values higher than that found in this article near the cubicle doorway—between 50 and 100 V m^{-1} during MW therapy—whereas in the corridors, according to type of treatment, values fell to 5–30 V m^{-1} but they did not clearly state the types of units tested.

We believe that a distance of 1 m provides a safety margin to protect against reflection and higher field applicators and is appropriate as a general recommendation for all MW equipment. However, in order to respect this limit, an adequate size of treatment cubicles is necessary.

Measurements of MW fields taken at several distances from a unit at 150 cm from the floor, decreased rapidly with distance and with reduction in power, almost to zero at ~120 cm from the unit, even at higher power density values. According to Martin *et al.*[13,14], this decrease was even greater for measurements at the height of the gonads and eyes. Li and Feng[18] reported that the EMF values of MW units fell to zero at 150 cm from the electrodes.

Some EMF measurements in the work environment were different at the same distance from the equipment, probably because metal conducting



Legend:

Machine	Model	Output power (W)
a	Roland RX 250 P.2	150
b	Biohelp	80
c	Cosmogamma	110
d	Roland RX 250 P.2	150
e	Biohelp	60
f	Sanitas Megatherm 200 N	80
g	Sanitas Megatherm 250	60
h	Roland RX 250 P.2	20
i	Sanitas Megatherm 200 N	80
l	Sanitas Megatherm 200 N	80
m	Roland RX 250 P.2	20

Figure 1. Electromagnetic field values measured at consoles of all MW therapy. Directive action values (**A**) $E = 137$ V m^{-1}, (**B**) $H = 0.36$ A m^{-1} and (**C**) $S = 50$ W m^{-2}.

Table 4. Range of mean measurements of electromagnetic fields emitted by four MW therapy units (two Roland RX 250P and two Biohelp), at varying distances (*d*) from source of radiation, in several types of physiotherapy clinics.

Zone	d (m)	E (V /m^{-1})	H (A /m^{-1})	S (W m^{-2})
Applicators	0.5	13.51–139.31	0.35–0.36	0.48–51.5
Console	1	19.08–32.79	0.05–0.086	1.14–3.44
Adjacent cubicle	1.5–2	8.83–11.46	0.023–0.03	0.23–0.38
Corridor	2–3	7.36–12.39	0.015–0.032	0.11–0.41
Other cubicles	3–6	1.39–6.99	0.002–0.018	0–0.148
Corridor	4–8	1.05–2.98	0.002–0.007	0–0.033
Other positions	7–8	1.27–1.61	0.002–0.004	0.004–0.006

material (e.g. curtain rods, chairs, etc.), may reflect or perturb the fields. Operators should avoid standing in the vicinity of large metal objects that could reflect the MW radiation to control overexposure to fields[12]. This is possible with technical and organisational measures such as a correct design and layout of workplaces and delimitation of treatment areas to avoid unnecessary exposures. Therefore, the only way to be sure of the exact field emitted by a unit is to take measurements specifically on that unit, so that safety procedures can be adapted to that particular situation.

Contour maps between 0° and 180° around the cylindrical applicator confirm, as reported by other authors[19], radiation between 30° and 150° with peak on the central axis at 90°, whereas the rectangular parabolic applicator shows distribution through 180°, with peaks between 30° and 150°. Therefore, during treatment, operators should not stand close to applicators, nor at the side when using parabolic ones, and should position both their patients and the applicators towards solid walls rather than towards partitions or cubicle doorways; therefore, organisation of operator's work for limitation of the duration and intensity of the exposure and provision of worker information and training would be suitable. Skotte[15], who mapped zones around various types of MW and SWD applicators, found considerable differences in emission according to type of applicator: 'air-gap' electrodes, i.e. composed of two electrodes, emit at greater intensity; 'circuplodes', composed of a single electrode, emit at lower intensity. According to the above author, distance from the applicators is important in reducing exposure; operators are advised to position themselves behind the console, opposite the applicators and the various leads and cables belonging to the unit[14].

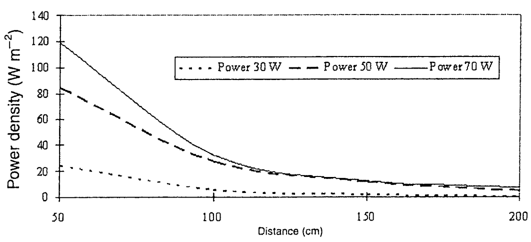


Figure 2. Variations in power density (W m^{-2}) according to the distance from MW applicator, at varying powers.

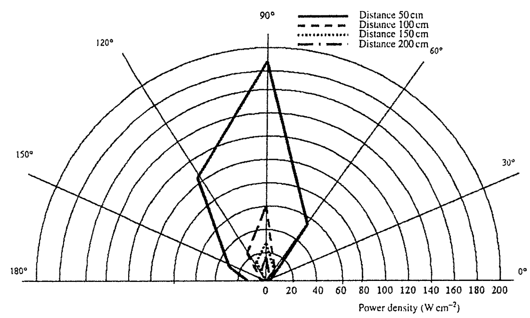


Figure 3. Angular distributions at height of 150 cm of power density near cylindrical electrodes of Biohelp MW unit. Power 110 W.

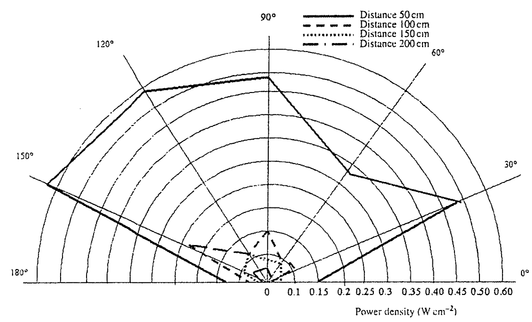
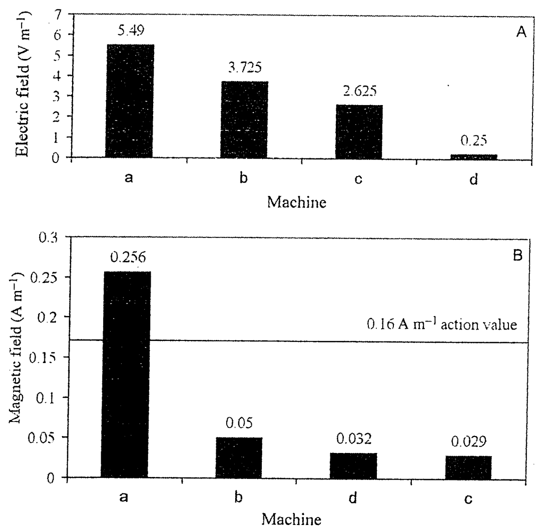


Figure 4. Angular distributions at height of 150 cm of power density near parabolic applicator of of Biohelp MW unit. Power 80 W.



Legend	Machine	Model	Output power (W)
	a	Sanitas Thermosan 2010	300
	b	Enraf Curapuls 419	125
	c	Enraf Curapuls 419	125
	d	Enraf Curapuls 419	125

Figure 5. Electromagnetic field values measured at consoles of SWD units. Directive action values (**A**) $E = 61\ \mathrm{V\ m^{-1}}$ and (**B**) $H = 0.16\ \mathrm{A\ m^{-1}}$.

SWD equipment

H-field behind a console of SWD was higher than Directive action value. This value ($0.256\ \mathrm{A\ m^{-1}}$) was measured for a unit inside a small cubicle, which obliged the operator to stand at one side of the applicator (at a distance of 1 m). In order to reduce the exposure during the first few minutes of a treatment, when electrodes are used, it is important that the operator stand at the end of the console, opposite the applicator. Other measurements behind the consoles and reported by environmental maps all fell below international occupational exposure limits.

As reported by Li and Feng[18], for SWD units, which often emit variable fields, the risk of overexposure would be limited to ***H***-field, with values of $0.34\ \mathrm{A\ m^{-1}}$ at 20 cm from the electrodes; this value decreases with distance and, already at >20 cm, according to the above authors, possible overexposure can be avoided; however, the recommendation was based on measurements from only one unit. For Martin *et al.*[13], if the operator remains at least 1 m from SWD electrodes during the majority of any treatment and does not approach within 0.5 m of electrodes or cables, the risk of exceeding the relative exposure level is low. In addition, in their view, the fields generated by pulsed SWD are generally much lower than continuous waves. Casciardi *et al.*[16] and Grandi *et al.*[17] found, in SWD therapy, ***E***-field intensities of $1000-2000\ \mathrm{V\ m^{-1}}$ at 10 cm from the applicators.

Environmental mapping showed values decreasing with distance. Other authors[15, 16] have measured ***E***-field values higher than that found in this article near the cubicle doorway between 10 and $30\ \mathrm{V\ m^{-1}}$ during SWD treatments, whereas in the corridors, according to type of treatment, values fell to $10-100\ \mathrm{V\ m^{-1}}$[16]; in the study by Skotte[15], the measurement error was estimated to be on the order of 20%. A recent study by Shields *et al.*[11] demonstrated high levels of stray field emitted from SWD units. The authors, who tested different types of equipment and applicators, concluded that physiotherapists should remain 1.5–2 m from capactive SWD and 1 m from inductive SWD.

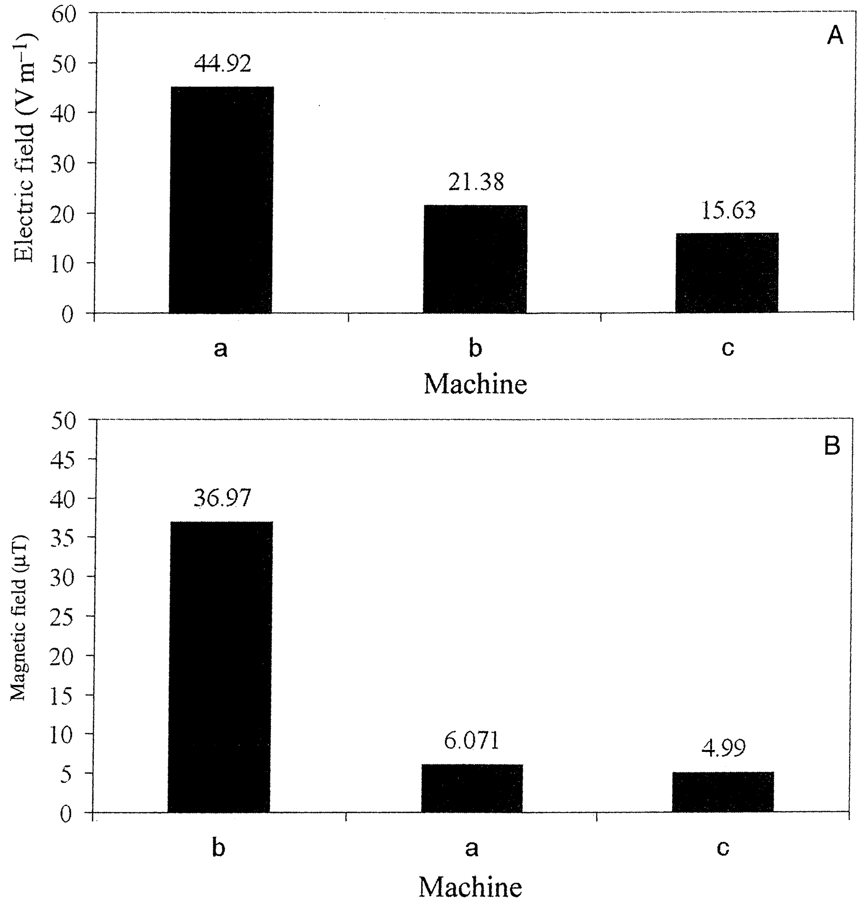
The results suggest that worker information and training on safe working practices to minimise risks from exposure are necessary, but also appropriate maintenance programmes for work equipment with periodic environmental monitoring are required; furthermore as overexposure is possible, health surveillance of the workers with the objective of prevention and early diagnosis of any adverse effects due to the exposure to electromagnetic fields is also appropriate.

Table 5. Range of mean measurements of electromagnetic fields emitted by four SWD units, at varying distances (*d*) from source of radiation, in several types of physiotherapy clinics.

Zone	d (m)	E ($\mathrm{V\ m^{-1}}$)	H ($\mathrm{A\ m^{-1}}$)
Console	1	0.25–5.49	0.029–0.256
Adjacent cubicle	1.5	1.12–2.04	0.03–0.06
Corridor	2–3	0.53–1.39	0
Other cubicles	3	0.22	0

Magneto therapy

Magneto therapies ***E***- and ***B***-fields were all below the exposure levels behind the consoles and on the environmental map. The ***B***-field strengths at the consoles associated with fixed units were significantly larger than those with the portable units. Furthermore, environmental maps showed ***B*** values of fixed units higher than 0.4 μT, residential 50 Hz magnetic field level indicated by IARC[7] with no increased risk for childhood leukaemia, up to a distance of 3–6 m from the solenoids. So, there is a potential overexposure for operators and patients in



Legend	Machine	Model	Output magnetic field intensity (μT)
	a	Sanitas electric	1000
	b	ASA Pmt 4 Pro	600
	c	ASA Pmt 4 Pro	510

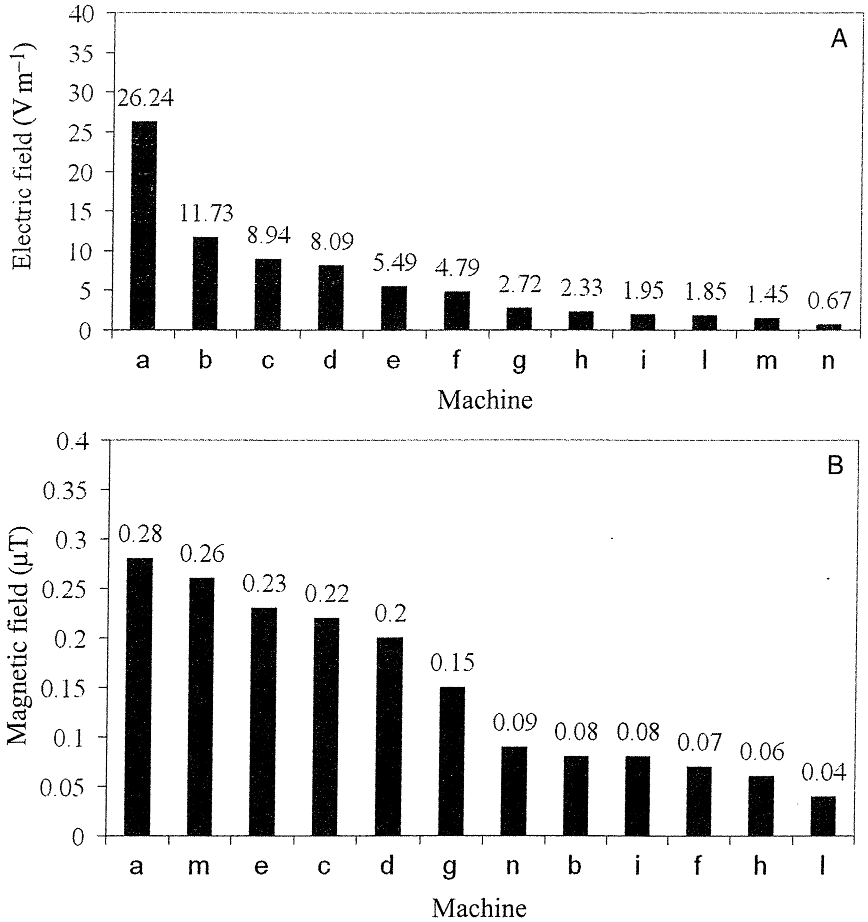
Figure 6. Electromagnetic field values measured at consoles of fixed magnetic therapy units. Directive action values (A) $E = 10\,000$ V m^{-1} and (B) $H = 500$ μT.

adjacent cubicles undergoing other treatments. Nevertheless, the time of exposure for other patients is negligible, being limited to 20–40 min d^{-1} for few weeks, and, regarding occupational exposure, most research has found no evidence of increased risk for any kind of cancer[5,7,20].

In corridors and adjacent cubicles, ***B***-field values ranged between 0.3 and 20 μT. Casciardi *et al.*[16] also measured high ***B***-field values (200 μT) near fixed magneto therapy consoles, but much lower values—between 5 and 10 μT—for local applicators. The ELF fields are less with the patient than without because the presence of the patient can perturb the field and make readings different: the differences are higher near the applicator (at a distance of 1 m) than at a greater distance (4 m).

CONCLUSIONS

The total number of units tested, 30, was greater than in previous study and we also examined 15



Legend Machine	Model	Output magnetic field intensity (μT)
a	Igea srl Biostim (R2000)	200
b	Igea srl Unix	200
c	Igea srl Biostim (R2000)	200
d	Igea srl Biostim (R2000)	200
e	Bn Magneton CMP 100	500
f	Sanitas Therodore 27	300
g	Bn Magneton CMP 100	500
h	Igea srl Unix	200
i	Molinari R. MDM 800	500
l	Igea srl Unix	200
m	Molinari R. MDM 800	500
n	Sanitas Therodore 27	300

Figure 7. Electromagnetic field values measured at consoles of portable magneto therapy units. Directive action values (**A**) $E = 10\,000$ V m^{-1} and (**B**) $H = 500$ μT.

Table 6. Range of mean measurements of electromagnetic fields emitted by three magneto therapy units, at varying distances (*d*) from source of radiation, in several types of physiotherapy clinics.

Zone	*d* (m)	*E* (V m^{-1})	*B* (μT)
Console	1	15.63–44.92	4.99–36.97
Adjacent cubicle	1.5–2	16.8–28.96	0.60–9.64
Corridor	2–4	1.25–15.7	0.04–12.7
Other cubicles	3–6	1.87–35.032	0.104–4.28
Corridor	4–7	0.85–0.87	0.026–0.110

magneto units, which were tested in only one study[16].

Our results show substantially low levels of occupational exposure to electromagnetic fields in physiotherapy clinics. Operators are exposed to sources of short waves and MWs for short periods of time, and exposure levels are often under the recommended limits. The dominant source of fields may be the leads at the consoles and near the electrodes; exposure exceeding the limits was found near MW electrodes and behind a SWD console. Recommendations that the operator not stand closer than a distance of 1 m of the various electrodes, if not for a short period, is appropriate. Furthermore, in clinics where patients are treated in adjacent cubicles, a space of at least 1–2 m should be left between couches to protect other patients and physiotherapists when the field is on. An adequate distance is also important for magneto therapy.

The intensity of the fields emitted by MW units decreases rapidly with distance from the electrodes and with reduction of power. This is not always true in work environments, since nearby metal accessories interfere with field emissions. In addition, the shape of the applicator head influences the field intensity emitted: MWs emitted from cylindrical heads peak to 90°, whereas rectangular parabolic heads emitting over 180° peak between 30° and 150°.

Table 7. Mean measurements of electromagnetic fields emitted by one magneto therapy unit (Asa Pmt 5 Pro; $P=600$ μT), at varying distances (*d*) from source of radiation, with (*) and without (°) the patient.

Zone	*d* (m)	*E** (V m^{-1})	*E*° (V m^{-1})	*B** (μT)	*B*° (μT)
Console	1	32.37	38.253	11.731	15.36
Corridor	1.5	16.78	20.40	5.521	8.035
Adjacent cubicle	2	22.248	23.69	5.795	7.78
Corridor	2.5	14.62	15.25	4.641	5.639
Other cubicles	4	1.733	2.521	1.267	1.565

values

In conclusion, our results reveal that although most areas show substantially low levels of occupational exposure to electromagnetic fields in physiotherapy units, certain cases of over-occupational exposure limits do exist. To obtain further reduction of worker exposure, some structural, organizational and control measures must be adopted.

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