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ORIGINAL ARTICLE / *ARTIGO ORIGINAL*

Prevalence of fatigue reported by physiotherapists operating diathermy equipment for microwave

Prevalência de fadiga referida por fisioterapeutas que operam equipamentos de diatermia por micro-ondas

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ABSTRACT: ***Objective:*** To Analyze the association between prevalence of fatigue referred by physical therapists and their occupational exposure to radiation emitted by therapeutic microwave diathermy equipment. ***Methods:*** A Cross-sectional study conducted in 193 physical therapists from four cities of the west of Paraná State, Brazil. A specified structured web questionnaire was applied for collecting data about microwave diathermy exposition and potential confounders, plus the Multidimensional Assessment of Fatigue (MAF). Statistical analysis included logistic regression and Student's *t*-test. ***Results:*** The prevalence of fatigue in the category exposed to microwave diathermy was higher (15.0%) than in non-exposed (2.9%). On multivariate logistic regression, a significant independent association between exposure to microwave diathermy and prevalence of fatigue was observed (odds ratio 4.93; 95% confidence interval 1.04 – 23.25; p = 0.04). The Student's *t*-test showed significant difference between the number of hours exposed to diathermy microwave, being 3,839.1 within physical therapists who referred fatigue and 497.6 within others (p = 0.004). ***Conclusion:*** The results demonstrate a significant and independent association between occupational exposure of physical therapists to radiation of microwave diathermy and prevalence of fatigue. Therefore, occupational safety guidelines aimed at these professionals as a prevention of possible adverse effects, as well as the replication of this study are suggested.

Keywords: Physical therapists. Fatigue. Occupational exposure. Diathermy. Microwaves. Epidemiology.

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RESUMO: ***Objetivo:*** Analisar a associação entre a prevalência de fadiga referida por fisioterapeutas e a exposição desses profissionais à radiação emitida por equipamentos terapêuticos de diatermia por micro-ondas. ***Metodologia:*** Foi realizado estudo de corte transversal com 193 fisioterapeutas de quatro municípios da região Oeste do Estado do Paraná, Brasil. Foi aplicado, via eletrônica, questionário estruturado especialmente para a coleta de dados sobre a exposição ocupacional à radiação emitida por equipamentos de diatermia por micro-ondas e potenciais fatores de confusão, acrescido do questionário de Avaliação Multidimensional de Fadiga. A análise estatística incluiu regressão logística e teste *t* de Student. ***Resultados:*** A prevalência de fadiga na categoria expostos a micro-ondas foi maior (15,0%) do que em não expostos (2,9%). Na regressão logística multivariada foi observada associação independente significante entre a exposição ocupacional de fisioterapeutas à radiação de diatermia por micro-ondas e a prevalência de fadiga (*odds ratio* 4,93; intervalo de confiança de 95% 1,04 – 23,25; p = 0,04). O teste *t* de Student mostrou diferença significante entre o número total de horas de exposição à radiação de diatermia por micro-ondas, sendo de 3.891,1 entre os fisioterapeutas que referiram fadiga e de 497,6 entre os que não referiram (p = 0,004). ***Conclusão:*** Os resultados demonstraram associação significante entre a exposição ocupacional de fisioterapeutas à radiação emitida por equipamentos de diatermia por micro-ondas e fadiga, portanto, são sugeridas orientações de segurança ocupacional, dirigidas a esses profissionais, como medida preventiva de possíveis efeitos adversos, e a replicação deste estudo.

Palavras-chave: Fisioterapeutas. Fadiga. Exposição ocupacional. Diatermia. Micro-ondas. Epidemiologia.

INTRODUCTION

The physical therapist uses different types of electro-electronic equipment that emit electromagnetic radiation for therapeutic purposes. One of them is the microwave diathermy equipment (MDE), which is used in physical therapy to obtain the characteristic effects of therapy through heat, such as the analgesic, anti-inflammatory effect and antispasmodic effect[1]. The MDE emits high frequency, non-ionizing radiation, of 2.45 GHz[2].

The radiation of MDE is emitted through an applier that is directed to the region of the body that will be treated, at a distance of 2.5 to 50 cm for 5 to 10 minutes, according to the proposed therapeutic purpose established by the physical therapist.

This therapeutic procedure may cause different losses, caused by reflection and dispersion of the energy that is irradiated from the applier toward the area to be treated[1].

The professional who operates the MDE is daily exposed to the radiation emitted by this equipment, and such occupational exposure may last for several years. It is possible to observe that the physical therapist, in general, rarely adopts attitudes concerning occupational safety during therapeutic applications of MDE, such as stepping away immediately after the beginning of the application, and remaining away from the applier, at a safe distance of one meter, as suggested by a study conducted by Anguera[3], until the conclusion of the

procedure, since the intensity of the electric field decreases when the distance from the generating source increases[4].

In general, being exposed to a uniform electromagnetic field (EMF), that is, with constant intensity[4], leads to deposition and distribution of highly non-uniform energy inside the body[5], and the consequence of that is the production of heat spots inside the biological material. Such spots, especially in regions with less efficient mechanisms of heat transfer, may lead to specific changes in the tissue, even if body temperature in general does not increase significantly[6]. Under normal circumstances of increasing localized heat, the blood vessels dilate and the heat is removed by the bloodstream. Therefore, the main risk of thermal damage is concentrated in areas of low vascularity, like the eyes[7].

Laboratory studies suggest that adverse biological effects may be caused by temperatures that increase more than 1ºC[8].

The results of EMF absorption by different types of human tissues are well known and work as a base to limit the levels of absorption of energy referred by the guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP)[5]. These guidelines are officially recognized by the World Health Organization (WHO)[9], and are based on immediate and short term health effects, such as stimulation of peripheral nerves and muscles, shocks and burns caused by touching conductive objects and increasing temperature in the tissues, which is a result of the absorption of energy during the exposure to EMF. Until now, the hypothesis is that reports indicating potential non-thermal effects do not constitute sufficient evidence to establish limits[5].

According to Vecchia, in the preface of the book Medidas do Campo Elétrico Gerado por Equipamentos de Micro-ondas de Uso Terapêutico Durante Aplicação Clínica[3] (Measurements of the Electric Field Generated by Therapeutic Microwave Equipment during Clinical Application), the guidelines of ICNIRP are a reference for more than 30 countries all over the world, including Brazil, which approved the National Legislation n. 11.934, on May 5, 2009, which concerns the protection against EMF and recognizes the importance of reference standards for the exposure to non-ionizing radiation. As described in the 1st article, sole paragraph of the aforementioned law, services that use radio communication transmitters, suppliers of user terminals that are commercialized in the country and authorized dealers and licensed companies of electric energy services are subject to the obligations established by that law.

It is possible to observe that the adverse effects associated with the occupational exposure of physical therapists to non-ionizing radiation, especially in the microwave frequency, has been timidly investigated by studies.

Four epidemiological studies involving physical therapists and the exposure to microwaves presented results related to reproduction and suggested associations with infertility[10], spontaneous abortion[11] and birth defects[12].

A study conducted by mail in the USA with physical therapists exposed to microwave and shortwave radiation and, including time of service, showed significantly higher prevalence of heart disease, with odds ratio (OR) of 2 – 3[13].

The main results of occupational health involving professional activities in different fields and exposure to radiofrequency/microwaves (RF/MW) include neoplasms, brain, breast, testicular and lung cancer, ocular melanoma and leukemia; there were other results, such as ocular conditions, heart and reproductive diseases. Up until now, these epidemiological results suggest higher occupational risks of cancer resulting from the chronic exposure to higher densities of RF/MW power, for several groups, such as radar operators, telecommunication technicians, maintenance technicians, among others. No consistent effect was demonstrated, but these effects cannot be refuted due to the low quality and short duration of the cohort and case-control studies that have been conducted so far[14].

Symptoms such as discomfort, headache, fatigue, nausea, among others, have also been investigated in epidemiological studies. According to the Commission of Latin-American Experts in High Frequency Electromagnetic Fields and Human Health, most of these studies, which aimed at analyzing the acute effects of the exposure, did not find an association with symptoms during or right after the exposure[14].

RF/MW in particular may interfere in implanted medical devices, such as the pacemaker[15], but, in that case, the effects on health would be a consequence of the intervention of RF and MW on the device, therefore not resulting from a direct effect on the body. So, these effects are not discussed in this analysis.

WHO officially declared that all of the opinions of experts about the effects of exposure to RF fields on health reached the same conclusion: there are no adverse consequences to health established from the exposure to RF fields when levels are below the international guidelines about exposure limits, published by ICNIRP in 1998[16].

However, nowadays there is a global concern about the occupational audience that is exposed to EMF, considering that these people are not rarely exposed in environments with levels of absorption of electromagnetic energy that are superior to those suggested limits. This concern was demonstrated in the last workshop held by ICNIRP, on May 9 to 11, 2012, in Edinburg. Most presentations emphasized the effect of high frequency sources and activities to which reference levels for absorbing energy are outdated, such as the process of welding and diagnosis made by magnetic resonance imaging, among others. Occupational exposure to non-ionizing radiation above the suggested limits can occur in any professional activity that involves EMF, as well as in controlled or non-controlled environments, that is, with and without knowledge, respectively, from professionals who are exposed about levels of radiation, attributed risks and safety measures.

With the objective of contributing with the clarification of indicators that can arouse the interest of authorities related to surveillance and health legislation, with regard to attitudes addressed to the safety of professionals who are directly or indirectly involved with MDE therapy, justified by the possibility of adverse effects to the health of individuals who are exposed owed to occupation, fatigue was chosen for the analysis of association with exposure to MDE radiation.

Fatigue is understood as a subjective symptom of low vitality, which can be originated by environmental factors, among others; its effect is cumulative[17]. Nowadays, fatigue is among the adverse effects investigated in studies that involve the exposure to non-ionizing radiation[15].

Therefore, a population sample composed of physical therapists was investigated with the objective of analyzing the association between the prevalence of fatigue reported by these professional and occupational exposure to non-ionizing radiation emitted by MDE.

METHODOLOGY

CHARACTERIZATION OF THE STUDY POPULATION

The population of this study was comprised of 821 physical therapists, registered in the Regional Council of Physical Therapy and Occupational Therapy of the 8th region (CREFITO-8), in 2010, who worked in the cities of Cascavel, Foz do Iguaçu, Marechal Cândido Rondon or Toledo[18], all located in the West region of the State of Paraná.

SAMPLE CHARACTERIZATION

This is a convenience sample that collected information from 193 physical therapists, which ensured 0.80 power and considered the following parameters: 0.05 significance level, estimated proportion of physical therapists exposed to MDE of 10%, 5.5% error (Stata, sample calculation and statistical power estimation for cross-sectional studies).

STUDY DESIGN

In order to meet the objective of this study, we used the observational method for a cross-sectional study with data collection. The prevalence rate as an indicator of the frequency of fatigue was obtained by the ratio of number of physical therapists with fatigue x 100, divided by the number of individuals analyzed in the population, at the time. The measurement of association was OR.

STUDY VARIABLES

The adopted independent variables were: being occupationally exposed to MDE radiation or not; only the physical therapists who claimed to operate the equipment were considered as

being exposed. The dependent variable was determined by the prevalence of fatigue among physical therapists. Fatigue was measured by the questionnaire Multidimensional Assessment of Fatigue (MAF)[19]. This questionnaire consists of 16 items, which assess subjective aspects of fatigue, such as quantity, intensity, exhaustion, impact and duration. The subscales are combined to create a global fatigue index, which ranges from 1 (no fatigue) to 50 (extreme fatigue). In this study, fatigue was considered when the rate was ≥ 50.

The following variables were also obtained: age, sex, color, living close by to mobile telephone towers and transmission lines of high voltage energy, using a cell phone on a daily basis, daily habits (caffeine, cigarette and alcohol), working hours, occupational exposure to shortwave diathermy (SWD) radiation and information of occupational exposure to MDE, which enabled to create an index that quantifies the hours of total exposure of the professional until the moment of the study. The index was established as:

te = ndhe x nmde x nme

in which:
te: total exposure;
ndhe: number of daily hours of exposure;
nmde: number of monthly days of exposure;
nme: number of months of exposure.

PROCEDURE FOR DATA COLLECTION

The electronic format was used to perform to get in touch with the participants of the study for the first time, with the objective of presenting its objective and of encouraging them to participate effectively. The emission and reception of the questionnaire were forwarded to all of the participants in the same format, together with the informed consent form for the participation in the investigation. Those who did not adhere to this procedure were contacted by mail and, afterwards, by telephone.

STATISTICAL ANALYSIS

At first, the distribution of variables and the fatigue score were analyzed with a descriptive purpose. Afterwards, the association between fatigue and occupational exposure to MDE radiation was analyzed. A multiple logistic regression was conducted to study the independent effect of occupational exposure to MDE radiation. The Student's *t*-test was also applied.

This study was approved by the Research Ethics Committee of the Medical School at *Universidade de São Paulo*, Research Protocol n. 060/10.

RESULTS

The highest proportion of physical therapists participating in this study is ≤ 29 years old (52.85%). With regard to time of professional exercise, 53.88% has ≤ 5 years. Physical therapy is the only profession for 74.09% of the participants. Women are prevalent in the sample (72.20%), as well as white professionals (84.53%).

The lowest proportion of physical therapists in the sample (22.28%) works in places (clinics and/or hospitals) that use MDE as a therapeutic resource. From these physical therapists who work in places with MDE, 47.62% operate it. The mean time of this modality of therapeutic application, for 42.85% of them, is ≥ 15 minutes, and the prevalent daily mean of applications ranges from 2 to 5 (32.14%). The highest proportion of physical therapists (43.75%) are exposed to this type of radiation from 5 to 8 hours a day, and only 22.58% adopt some sort of occupational safety measure.

Among all of the investigated physical therapists, only 11.40% refer not to feel fatigue at all. Most of them (88.61%) feel some level of fatigue, being distributed as follows: 84.64% with scores ranging from 2 – 49.9, and 4.15% with scores ≥ 50.

The univariate analysis for the relationship with fatigue (Table 1) does not show a significant association with sex, color, living close to mobile telephone towers and transmission lines of high voltage energy, and daily use of a cell phone. The variables age ($p = 0.09$), occupational exposure to SWD radiation ($p = 0.06$) and daily habits ($p = 0.05$) did not present a significant association with fatigue, however, they presented $p < 0.20$. It was possible to observe a significant association ($p = 0.03$) between fatigue and the exposure to occupational exposure to SWD radiation, with OR of 5.89 (95%CI 1.29 – 26.84).

By comparing the univariate analysis with the initial model of the multivariate analysis (Table 2), it is possible to observe that variables regarding daily habits ($p = 0.09$) and exposure to SWD radiation ($p = 0.90$) become less important when adjusted by the exposure to MDE ($p = 0.13$) and age ($p = 0.08$).

In the final model of the multivariate analysis (Table 3), after the exclusion of the variables daily habits and occupational exposure to SWD radiation, it was observed that the association between fatigue and exposure to occupational MDE radiation, adjusted by age, is significant ($p = 0.04$), with OR of 4.93 (95%CI 1.04 – 23.25).

In order to rule out the confusion with working hours, its association with fatigue and occupational exposure to MDE radiation was also analyzed. The mean daily working hours for physical therapists who are occupationally exposed to MDE radiation and for those who are not is 7.05 and 7.68, respectively, and there was no significant association between fatigue and working hours ($p = 0.35$).

The difference between the average hours of occupational exposure to MDE radiation is significantly higher among physical therapists who reported fatigue (3,839.1 hours), in comparison to those who did not report it (497.6 hours). The Student's *t*-test shows that the result related to occupational exposure to MDE radiation and fatigue ($p = 0.004$) was consistent with the results obtained in the univariate and multivariate analyses for this outcome.

Table 1. Univariate analysis of the association between some analyzed variables and fatigue among physical therapists. West of the State of Paraná, Brazil, 2010 – 2011.

Variables	n	n1	%	χ^2	p-value	OR	95%CI
Sex							
Male	44	2	4.55	0.02	1.00	1.00	
Female	149	6	4.03			0.88	0.17 – 4.53
Age							
≤ 29 years old	102	2	1.96	4.83	0.09	1.00	
30 – 39 years old	65	3	4.62			2.42	0.39 – 14.89
≥ 40 years old	26	3	11.54			6.52	1.03 – 41.30
Color							
White	153	7	4.58	0.05	1.00	1.00	
Others	28	1	3.57			0.77	0.91 – 6.53
Daily habits							
No	135	3	2.22	4.18	0.05	1.00	
Yes	58	5	8.62			4.15	0.96 – 17.99
Swd exposure							
No	111	2	1.80	4.84	0.06	1.00	
Yes/does not use it	28	3	10.71			6.54	1.04 – 41.23
Yes/uses it	54	3	5.56			3.20	0.52 – 19.78
Living close by to high voltage							
No	90	4	4.44	0.34	0.47	1.00	
Yes	12	1	8.33			1.95	0.20 – 19.10
Living close by to high voltage							
No	92	4	4.35	0.03	1.00	1.00	
Yes	19	1	5.26			1.22	0.13 – 11.59
Daily use of cell phone							
< 10 min	98	3	3.06	2.79	0.26	1.00	
10 min – 1 h	78	3	3.85			1.27	0.25 – 6.46
> 1 h	17	2	11.76			4.22	0.65 – 27.40
Mde exposure							
No	172	5	2.91	6.56	0.03	1.00	
Yes	20	3	15.00			5.89	1.29 – 26.84

n1: number of people affected by fatigue; %: percentage of people affected by fatigue; OR: *odds ratio*; 95%CI: 95% confidence interval; SWD: short wave diathermy; MDE: microwave diathermy equipment.

Table 2. Initial model of the multivariate logistic regression* analysis between the risk variables chose for fatigue among physical therapists who are occupationally exposed to radiation emitted by therapeutic microwave diathermy equipment (n = 192) West of the State of Paraná, 2010 – 2011.

Variables	Adjust OR	SD	Z	p-value	ICI	SCI
SWD exposure	4.77	4.99	1.49	0.13	0.61	37.13
Age	2.43	1.26	1.71	0.08	0.87	6.75
Daily habits	3.64	2.80	1.68	0.09	0.80	16.50
MDE exposure	0.93	0.51	0.12	0.90	0.31	2.76

*adjusted model by exposure to occupational radiation of microwave diathermy equipment (MDE), age, daily habits and exposure to occupational radiation of short wave diathermy (SWD); Adjust OR: adjusted OR; SD: standard deviation; Z: standard normal distribution; ICI: inferior confidence interval; SCI: superior confidence interval; MDE: microwave diathermy equipment; SWD: short wave diathermy.

Table 3. Final model of the multivariate logistic regression* analysis between the risk variables chose for fatigue among physical therapists who are occupationally exposed to radiation emitted by therapeutic microwave diathermy equipment (n = 192) West of the State of Paraná, 2010 – 2011.

Variables	Adjust OR	SD	Z	p-value	ICI	SCI
MDE exposure	4.93	3.90	2.02	0.04	1.04	23.25
Age	2.37	1.16	1.76	0.07	0.90	6.19

*adjusted model by exposure to occupational radiation of microwave diathermy equipment (MDE) and age; Adjust OR: adjusted OR; SD: standard deviation; Z: standard normal distribution; ICI: inferior confidence interval; SCI: superior confidence interval; MDE: microwave diathermy equipment.

DISCUSSION

Technological evolution is also present in the health field, and the benefit of such an evolution favoring the general audience is clear; this study is not denying this fact. However, only a few studies were conducted involving the technologies that are available in the health field and use the EMF, especially for treatments with MDE; therefore, little has been analyzed about the adverse effects to the health of professionals who are exposed to this radiation, which could justify the lack of occupational safety measures adopted by the physical therapist, and such a situation is observed in clinical environments during MDE therapy.

This study was conducted with the objective of contributing with information related to the subject, and enabled the association between physical therapists who are occupationally exposed to microwave diathermy radiation and fatigue referred by the same professionals

The methodology we used as a questionnaire developed specifically for this investigation, and also MAF. It was applied virtually, in a population sample comprised of physical therapists from four cities located in the West region of the State of Paraná, in 2010 and 2011.

The female gender prevailed in the sample of this study, as well as the age group ≤ 29 years old and time of professional exercise ≤ 5 years.

The results in this study presented significant association between the occupational exposure of physical therapists to microwave diathermy radiation and fatigue.

The lack of a biological mechanism that can explain the interaction between the triad biological organism, EMF and fatigue should not be a reason to analyze the results obtained in this study by chance. According to a declaration from ICNIRP[15], even though the plausibility of several proposed mechanisms of biological interaction is low, it is impossible to deny its existence. Yet, in order for the results presented in this study to be considered as chance, it should be replicated.

CONCLUSION

The results in this study demonstrate a significant association between the occupational exposure of physical therapists to the radiation emitted by MDE and fatigue. However, due to the difficulty to isolate the referred occupational exposure from other likely exposures that are present in the work routine, as well as the possible presence of other environmental factors that were not analyzed in this study, which could contribute with the presence of fatigue, besides the uncertainties that surround this theme globally, further studies should be conducted on the matter.

The investigation of fatigue among physical therapists who are exposed to the radiation emitted by MDE, as conducted in this study, contributed with indicators so that the main actors involved in the matter, that is, those who are most interested in it or the ones who may work on the subject, for example, the scientific community, industry, government and the physical therapist, can pay attention to the treatment area, which uses electromedical radiofrequency equipment, specifically in the microwave frequency.

Based on the role played by each involved party, the idea is to reduce the possible occupational and environmental risks connected to MDE therapy: the scientific community, which should provide technical information and help to understand the benefits and risks of microwave therapy, to assist and assess the options of risk management, and to explain the available scientific information; the industry, which should inform about the benefits of the technology that is placed in the market, as well as its real risk; the government, which should regulate guidelines; and, finally, the physical therapist, who has the role of knowing how to manage the technological innovation that is available for treatments and, effectively, put the regulated preventive measures in practice.

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