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Original Research

Magnetic bed for the treatment of different somatic diseases: design and simulation

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Abstract: At present, sports injuries that occur during the practice of a sport or physical exercise are becoming more and more common, due to a series of predisposing factors that make an individual more susceptible to suffer these injuries. In Cuba there is a high prevalence of articular affections of knees and ankles, with a high prevalence in people older than 60 years old and soft tissue injury consultations are in the order of 45%. One of the applications of the electromagnetic field is in the treatment of different pathologies of the osteomuscular system (Soma). The objective of this work lies in the design of a magnetic bed with permanent magnets, in analogy to a circular Halbach type configuration for the treatment of different diseases of the soma, which consists of three main parts: the magnetic system, which generates magnetic induction for therapeutic purposes, the opening and closing system of the magnetic system, which allows the radial variation of the magnetic system and the patient-support bed system, which allows the positioning of the patient in the treatment area. The principle of operation is that the therapist selects the induction of the magnetic field and the homogeneity of the magnetic field, depending on the pathology(s) to be treated, through a software that controls the movement of the opening and closing system of the magnetic system and the patient-bed support system, which is coupled to a stepper motor reducer that ensures a precise and accurate positioning of the sample (or patient) according to the area to be treated, which allows more than 80% effectiveness of the therapy with respect to conventional treatment.

Keywords: Magnetic beds, Magnetic fields, Magnetotherapy

Introduction

The application of magnetic treatment in different branches of socio-economic activities such as industry, agriculture and medicine is becoming more and more important. In medicine, magnetic and electrical devices have been used mainly in the development of methods and equipment for the treatment of diseases, the diagnosis and study of alterations in the organism (imageonological methods) and the study of the adverse effects produced by these fields in living organisms. Osteoarticular (soma) disorders are one of the most frequent diseases nowadays; it is of vital importance to know how the electromagnetic field influences living beings in the first place; but also how man can manipulate it and use it to improve his life quality [1]. The magnetic device (or magnetic bed) is a device that generates a magnetic field in a certain region of space by means of active and/or passive devices. At present, the use of permanent magnets for the treatment and

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diagnosis of diseases is widespread; however, they have not been used as systemic stimulators for the treatment of diseases, which is the problem to be solved in the present research [2,3]. The object of the research is the application of the magnetic field in medicine using a magnetic device with permanent magnets and as a field of action the design of magnetic devices with permanent magnets. The objective is to design a magnetic device that has a magnetic system built with a circular configuration of permanent magnets, arranged in a non-metallic structure, which allows the displacement of the patient bed and the adjustable system of the magnetic system, according to the area of the patient to be treated, thus becoming a versatile product for the treatment of somatic diseases.

Materials and methods

The design of a magnetic device for the diagnosis and treatment of diseases is very complex. Here, parameters such as magnetic induction and homogeneity are taken into account, which depend on the designed configuration and on whether the device is active or passive. In the first case, we take into account the ampere-turn ratio, the shape and cross-section of the conductor, the thickness of the insulator, the distribution of the turns in layers and turns, and the dimensions and spacing between the coils that make up the magnetic system. In the second case, the type and dimension of the material, the magnetic induction and the magnetic gradient of the external field are taken into account; as well as the configuration used is discrete (permanent magnet elements) or continuous (bars, ferromagnetic loops) [4,5]. The magnetic system calculation is performed according to the following expression [6].

$$B(r) = \frac{\mu_0 1}{4\pi r^3}\left[3\hat{r}(m\cdot\hat{r})\hat{r} - m\right] \quad (1)$$

Where B(r), is the magnetic induction at the center of the configuration, μ_0 is the vacuum magnetic permeability, m is the dipole magnetic moment of the permanent magnets of Nd Fe B, r is the position vector; for this a computer program is used that solves a magnetostatic problem, in analogy to a Halbach-type circular configuration [7,8]. The configuration of the magnetic system is formed by 16 permanent magnets of (0.005 x 0.005 x 0.025) m, which were distributed in a non-ferromagnetic light cylindrical structure (PVC, aluminum or plastic), of radius R = 0.4 m; with respect to the z = 0 plane from the center of the configuration, which is sufficient for the desired purposes [9,10]. Material N 42 was proposed, according to [11, 12]. A longitudinal and controlled pilot study was carried out at the Provincial Center of Sports Medicine of Santiago de Cuba, in the period January-September 2019. Patients were referred from the traumatology consultation of said center with the diagnosis of post-traumatic knee synovitis. They were treated in the rehabilitation service of this sports institution. Eighty-two patients with post-traumatic knee synovitis between 15 and 35 years of age were treated: 52 males (52/82 = 63.4%) and 30 females (30/82 = 36.6%). They were randomly grouped into two experimental groups. The first group consisted of 39 patients (39/82 = 47.6%) who received conventional treatment (cryotherapy + ibuprofen + dipyrone), referred to as G1. Cryotherapy (ice pack) was applied three times a day for 15 min. Ibuprofen 400 mg (Ciron Drugs & Pharmaceuticals PVT. Lt, India) and dipyrone 500 mg (Ciron Drugs & Pharmaceuticals PVT. Lt, India) were administered orally every 8 h. This conventional treatment was applied for 10 days. Lt, India) every 8 h. The 39 patients of G1 were distributed into two age groups of 15-25 years (23/39 = 59.0%) and 26-35 years (16/39 = 41.0%). These 23 patients were divided into nine females (9/23 = 39.1%) and 14 males (14/23 = 60.9%), while the 16 patients were divided into seven females (7/16 = 43.8%) and nine males (9/16 = 56.2%). 43 patients (43/82 = 52.4%) who received treatment with a magnetic field for 20 min, called G2, formed the second group.

Results

The design of the magnetic device configuration (magnetic bed), to permanent magnets, was made taking into account the magnetic induction and homogeneity maps, as well as its size and weight. Figure 1 shows the magnetic induction map, and the Figure 2 magnetic field magnitude (Mag_B). The dimensions of the permanent magnets thickness, length and width were c = 0.005 m, a = 0.025 m and b = 0.05 m, respectively.

Figure 2 shows the magnetic field magnitude map (Mag_B), in the X, Y planes.

Figure 3 shows the design and construction of the magnetic device for the treatment of different pathologies, which is composed of channel beams that support the weights of the patient and the magnetic system. It has the possibility of being disassembled, increasing the possibility of being versatile.

Table 1 shows the distribution of patients with post-traumatic knee synovitis according to VAS before treatment by experimental group, age groups and gender.

Table 2 shows the distribution of patients with post-traumatic synovitis of the knee according to VAS by age group and sex with conventional treatment in 0; 5; 10; 15 and 20 days.

Table 3 shows age groups, genders and VAS in G2 at 0; 5; 10; 15 and 20 days.

Discussion

The configuration shown can be used for the desired purposes since the magnetic induction generated is sufficient to treat any type of pathology, which by means

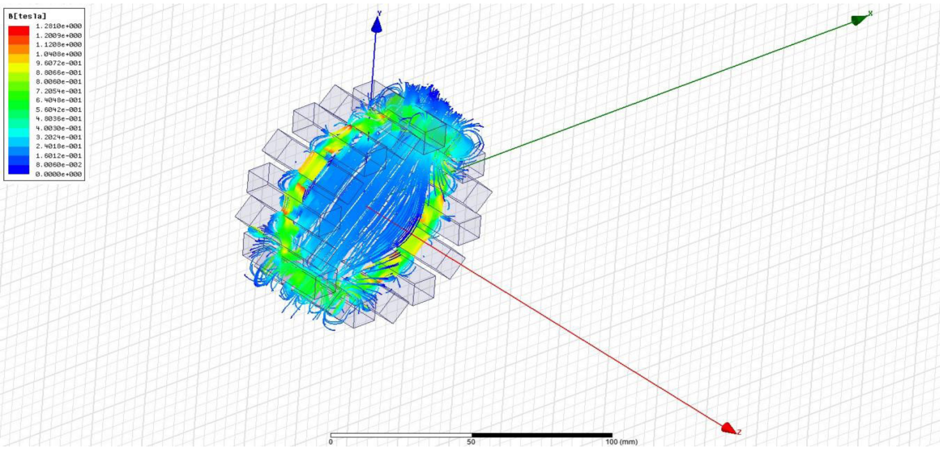

Figure 1. Magnetic induction map B = (12.35 to 25.2) mT in a sphere of radius r = 0.2 m. [13, 14]

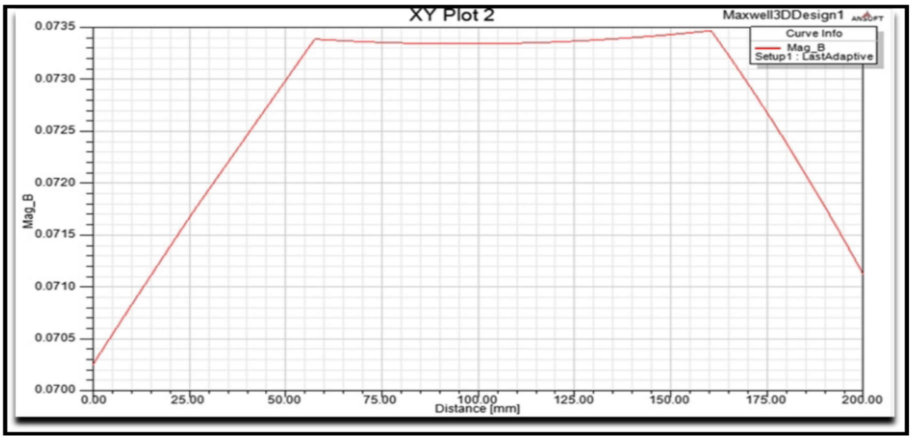

Figure 2. Magnetic field magnitude map (Mag_B) = (72.5 to a 73.5) mT in the X, Y plane; in a sphere of radius 0.2 m [15]

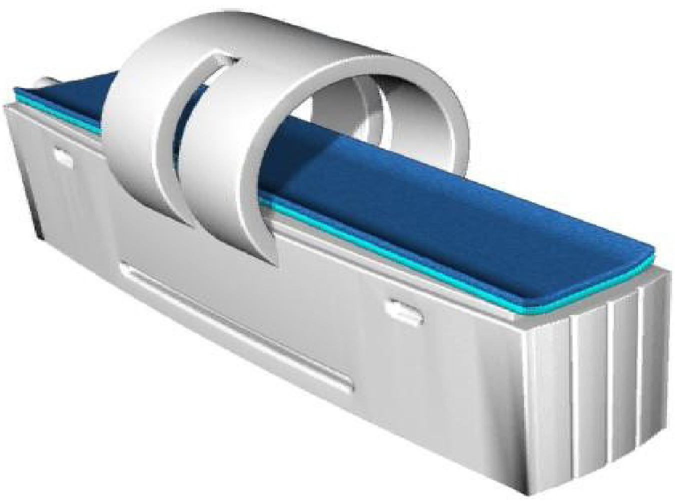

Figure 3. Permanent magnet magnetic device with adjustable magnetic system [16]

Table 1. Distribution of patients according to VAS before treatment by experimental group, age group and gender

Grupos experimentales (NT)	GE (N_{ge})	G (N_g)	EVA										
			10	9	8	7	6	5	4	3	2	1	0
G1 (39)	15-25 (23)	F (9)	2	1	1	3	-	2	-	-	-	-	-
		M (14)	2	3	4	4	1	-	-	-	-	-	-
	26-35 (16)	F (7)	4	1	-	1	-	1	-	-	-	-	-
		M (9)	2	2	1	2	-	2	-	-	-	-	-
G2	15-25 (37)	F (14)	1	-	12	1	-	-	-	-	-	-	-
(43)		M (23)	4	3	5	8	3	-	-	-	-	-	-
	26-35 (6)	F (0)	-	-	-	-	-	-	-	-	-	-	-
		M (6)	1	1	3	1	-	-	-	-	-	-	-

VAS: Visual Analog Scale. GE: age group. G: gender. NT was the total number of patients per experimental group. Nge and Ng were the numbers of patients per age group and gender, respectively. G1 was the group of patients with conventional treatment while G2 was the group of patients treated with magnetic field.

Table 2. Pain assessment, according to VAS, of patients with post-traumatic knee synovitis

Grupos experimentales (NT)	T_{obs} (días)	GE (N_{ge})	G (N_g)	EVA										
				10	9	8	7	6	5	4	3	2	1	0
	0	15-25 (23)	F (9)	2	1	1	3	-	2					
			M (14)	2	3	4	4	1						
		26-35 (16)	F (7)	4	1		1		1					
			M (9)	2	2	1	2		2					
	5	15-25 (23)	F (9)		1	2	1		3		1	1		
			M (14)			3	3	3	3	1	1			
		26-35 (16)	F (7)		2	1	2	-	-	1	1			
			M (9)			2	2	1	1	1	1	1		
	10	15-25 (23)	F (9)					2	1	1	1	2	-	2
			M (14)				1	3	3	3	1	2		
G1		26-35 (16)	F (7)					3	-	2	-	1	-	1
(39)			M (9)					2	2	1	1	1		2
	15	15-25 (23)	F (9)					2	1	1	1	2	-	2
			M (14)				1	3	3	3	1	2	1	
		26-35 (16)	F (7)					3	-	2	-	1	-	1
			M (9)					2	3	-	1	1	-	2
	20	15-25 (23)	F (9)					2	1	1	1	2	-	2
			M (14)				2	2	3	3	1	2	1	
		26-35 (16)	F (7)					3	-	2	-	1	-	1
			M (9)					2	3	-	1	1	-	2

VAS: Visual Analog Scale. GE: age group. G: gender. NT was the total number of patients per experimental group. Nge and Ng were the numbers of patients per age group and gender, respectively. Tobs was the observation time during the application of conventional treatment (G1).

Table 3. Pain assessment, according to VAS, of patients with post-traumatic knee synovitis treated with magnetic field at 0; 5; 10; 15 and 20 days, by age group and gender

Grupos experimentales (N_T)	T_{obs} (días)	GE (N_{ge})	G (N_g)	EVA 10	9	8	7	6	5	4	3	2	1	0
	0	15-25 (37)	F (14)	1		12	1							
			M (23)	4	3	5	8	3						
		26-35 (6)	F (0)											
			M (6)	1	1	3	1							
	5	15-25 (37)	F (14)			1	3	5	3	2				
			M (23)			3	4	4	5	6	1			
		26-35 (6)	F (0)											
			M (6)			1	-	1	2	2				
	10	15-25 (37)	F (14)					1	2	5	3	2	1	
			M (23)				1	-	7	4	6	5		
G2		26-35 (6)	F (0)											
(43)			M (6)					1			4	1		
	15	15-25 (37)	F (14)							1	2	4	3	4
			M (23)						1	1	4	6	6	5
		26-35 (6)	F (0)											
			M (6)							1	1	-	3	1
	20	15-25 (37)	F (14)									1	1	12
			M (23)								2	1		20
		26-35 (6)	F (0)											
			M (6)								1			5

VAS: Visual Analog Scale. GE: age group. G: gender. NT was the total number of patients per experimental group. Nge and Ng were the numbers of patients per age group and gender, respectively. Tobs was the observation time during the application of the mains magnetic field treatment (G2) [17].

of a software [18,19] which allows the therapist to select the magnetic induction and homogeneity, according to the type of pathology to be treated. In the Table 1 it was revealed that post-traumatic knee synovitis predominated in the male gender and the age group of 15-25 years for G1 and G2. It was observed that all patients were homogeneously distributed on the 5-10 scales for G1 and 6-10 for G2, except for the 12 females (12/14 = 85.7%), aged 15-25 years in G2, who were distributed on VAS 8. However, analysis by range showed that the pain of all patients was moderate (9/82 = 11.0%) to unbearable (16/82 = 19.5%), with severe (57/82 = 69.5%) being notable. In G1, 15.4% (6/39), 59.0% (23/39) and 25.6% (10/39) reported moderate, severe and unbearable pain, respectively. In G2, 7.0% (3/43), 76.7% (33/43) and 16.3% (6/43) reported moderate, severe and unbearable pain, respectively at Table 2 it was evident that at baseline (t = 0 days), females were mainly distributed in absolute scales 5; 7 and 10 (for age group 15-25 years) and absolute scale 10 (for age group 26-35 years).

In the Table 2 it was showed the evaluation of conventional treatment, according to VAS, of patients with post-traumatic knee synovitis treated with at 0; 5; 10; 15 and 20 days, by age group and gender which fully confirms what was predicted in the physical examination of the knee and does not depend on the type of therapy or the patient with post-traumatic synovitis of the knee, which may corroborate why conventional therapy does not achieve a cure in all patients after 20 days, despite pain relief.

In Table 3 it was shown that at the start of treatment at the beginning of treatment (t = 0 days), females were distributed from absolute scales 7 to 10 for the age group 15-25 years, being remarkable for scale 8 (12/14 = 85.7%). In this case, a protocol was carried out which showed a favorable evolution for all age groups; during the 15 days with an effectiveness of (80%), with respect to conventional treatment. The results of this study demonstrate that the applied therapy is feasible for patients with post-traumatic knee synovitis, in agreement with other scientific reports [20].

Conclusion

The permanent magnet magnetic device does not require recalibration maintenance once installed, except for the associated electronics for the movement of the patient bed and the mechanical device that allows the opening and closing movement of the coils. This lowers the maintenance cost of the equipment. The results of the simulations shown in this study suggest that the cylindrical configuration with its adjustable mechanism is feasible for the design of the permanent magnet device for the treatment of different pathologies. The software can be used to know the influence of each zonal or radial harmonic in the magnetic field, which would allow the study of how each of these influences the therapeutic effectiveness of this physical agent. The construction of this prototype will allow enhancing the applications of permanent magnets in the treatment of different pathologies in order to improve the quality of human life and substitute imports.

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