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

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; in the province of Santiago de Cuba 45% of the total number of consultations correspond to soft tissue injuries. 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

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Leonardo Mesa Torres,[1] Jorge Luis García Rodriguez,[1] Alejandro Alberto Bordelois Cayamo[2]

[1]National Center of Applied Electromagnetism, University of Oriente, Cuba
[2]Medical Biophysics Center, University of Oriente, Cuba

Correspondence: Leonardo Mesa Torres, National Center of Applied Electromagnetism, University of Oriente, Apartado Postal 4078, Zip Code 90400, Cuba,
Email leonardit@uo.edu.cu

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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 quality of life.[1,16] 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 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 this magnetic device was very complex because it had to take into account some 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.[8]

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

where B(r), is the magnetic induction at the center of the configuration, μ0 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.[6,7] 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.[12,13] 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. This conventional treatment was applied for 10 days. 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 of the (17,2-3,42) mT for 20 min, called G2, formed the second group. Twenty sessions of this physical agent were applied (from Monday to Friday with interruption on weekends), the patient lay down in the supine decubitus position. The magnetic applicator was fixed in this area. The 43 patients of G2 were distributed in two age groups of 15-25 years (37/43 = 86.0%) and 26-35 years (6/43 = 14.0%). In turn, these 37 patients were divided into 14 females (14/37 = 37.8%) and 23 males (23/37 = 62.2%) while the six patients were divided into no females (0/6 = 0.0%) and six males (6/6 = 100.0%).

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 1a) shows the magnetic field induction map, Figure 1b) magnetic induction vector (B), and the (2) magnetic field magnitude (Mag_B).

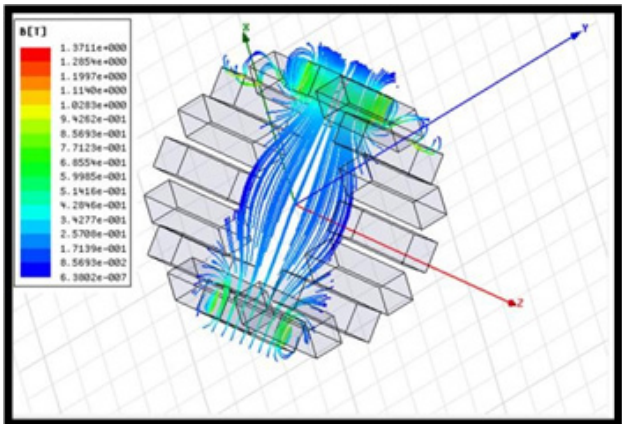

Figure 1a) Magnetic field induction map, B = (17,2 – 34,2) mT.

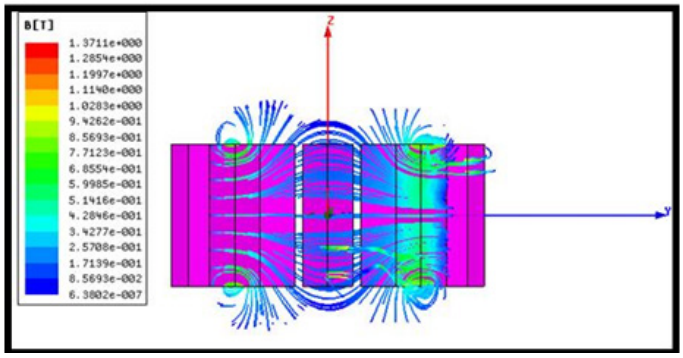

Figure 1b) Magnetic induction vector map, B = (25,7 – 42,8) mT.

The dimensions of the permanent magnets were: thickness (0,005) m, length (0,025) m and width (0,05) m respectively The first two variables are calculated, in a spherical volume of radius (r = 0,2) m; in the center of the configuration.[11,14] Figure 2 shows the magnetic field magnitude map (Mag_B), in the X, Y planes.

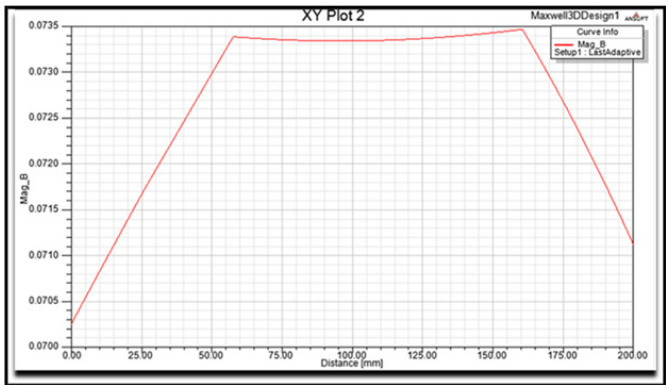

Figure 2 Magnetic field magnitude map (Mag_B) = (72.5-73.5) mT in the X Y plane; in a sphere of radius 0.2 m.[17]

Magnetic field magnitude map (Mag_B) = (72.5-73.5) mT in the X Y plane; in a sphere of radius 0.2 m.[17] 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.

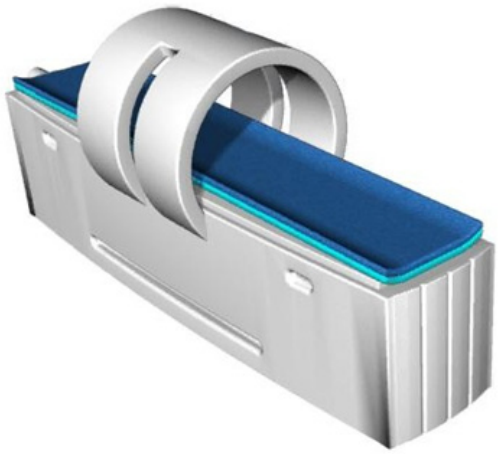

Figure 3 Permanent magnet magnetic device with adjustable magnetic system.[15]

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 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.

Table 2 shows the distribution of patients with post-traumatic knee synovitis according to age group, gender and VAS in G1 at 0; 5; 10; 15 and 20 days (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). However, males were mainly distributed in absolute scales 7; 8 and 9 (for the 15-25 age groups) and absolute scales 5; 7; 9 and 10 (for the 26-35 age groups). The analysis by age group showed that patients were essentially distributed in absolute scales 7 and 10 for age groups 15-25 and 26-35 years, respectively. The patients in G1 were mainly concentrated in absolute scales 10 (10/39 = 25.7%), 7 (10/39 = 25.6%), 9 (7/39 = 18.0%) and 8 (6/39 = 15.4%). 55.56% (5/9) of the female patients were distributed in the range 7-9 (for the age group 15-25 years) and 57.1% (4/7) in the scale 10 (for the age group 26-35 years). 78.5% (11/14) and 55.6% (5/9) of male patients were distributed in the range 7-9 for the age groups 15-25 and 26 -35 years, respectively. 69.6% (16/23) of patients were distributed in the 7-9 range for the 15-25 age group; however, 81.2% (13/16) were clustered in the 7-9 (7/16 = 43.8%) and 10 (6/16 = 37.5%) ranges for the 26-35 age group. As for G1, 59.0% (23/39); 25.6% (10/39) and 15.4% (6/39) of patients clustered in the ranges 7-9; 10 and 4-6. The absolute pain scale was modified over time when conventional treatment was applied, according to VAS (Table 2). At 20 days of observation, females were distributed mainly in absolute scales 6; 2 and 0 for the 15-25 years age group while they were grouped in absolute scales 6 and 4 for the 26-35 years age group. However, males were distributed in absolute scales 7; 6; 5; 4 and 2 for the 15-25 years age group and in scales 6; 5 and 0 for the 26-35 years age group. Patients were distributed indistinctly on the absolute scales 6; 5; 4 and 2 for the 15-25 years age group while they were clustered mainly on the absolute scale of 6 and less on those of 5 and 0 for the 26-35 years age group. G1 patients were concentrated mainly in the absolute scales 6 (9/39 = 23.1%), 5 (7/39 = 18.0%), 4 (6/39 = 15.4%) and 2 (6/39 = 15.4%). Twenty days after the start of the experiment, it was evident from Table 2 from the analysis by VAS range that the females in the 15-25 years age group were distributed in 44.4% (4/9); 33.3% (3/9) and 22.3% (2/9) in the VAS ranges 4-6, 1-3 and 0, respectively. The 71.4% (5/7) of the females in the age group 26-35 years were grouped primarily in the EVA 4-6 range. However, 57.1% (8/14) of male patients in the 15-25 age group and 55.6% (5/9) in the 26-35 age group were in the VAS 4-6 range. 52.2% (12/23) and 62.5% (10/16) of patients in the age groups 15-25 and 26-35 years were distributed in the EVA 4-6 range, respectively. In addition, Table 2 visualized the grouping of G1 patients in VAS ranges 7-9 (2/39 = 5.1%), 4-6 (22/39 = 56.4%), 1-3 (10/39 = 25.6%) and 0 (5/39 = 12.6%).

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

Experimental groups	GE(N)ge)	G(N)g)	EVE										
(No.you)			10	9	8	7	6	5	4	3	2	1	0
G1	15-25 (23)	F (9)	2	1	1	3	-	2	-	-	-	-	-
-39		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 by 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 Evaluation of pain, according to VAS, of patients with post-traumatic knee synovitis treated with conventional treatment at 0; 5; 10; 15 and 20 days, by age group and gender

groups (No.you)	experimental	you_{obs}	$GE(N)_{ge}$)	$G(N)_g$)	EVE										
		(days)			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
		fifteen	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

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Table Continued...

groups experimental (No.you)	you$_{obs}$	GE(N)$_{ge}$)	G(N)$_g$)	EVE								
			M (9)		2	3	-	1	1	-	2	
	twenty	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 by age group and gender, respectively. Tobs was the observation time during the application of conventional treatment (G1).

Table 3 shows age groups, genders and VAS in G2 at 0; 5; 10; 15 and 20 days. It was evident that 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%). However, males were concentrated on absolute scales 6 to 10 for the age group 15-25 years, being marked for scale 7 (8/23 = 34.8%). They were clustered from the absolute scales 7 to 10 for the age group 26-35 years, being marked for scale 8 (3/6 = 50%). The analysis by age group showed that the patients were essentially distributed on absolute scales 7 and 8 for the 15-25 years age group, while they were concentrated on scale 8 for the 26-35 years age group. G2 patients were concentrated mainly in absolute scales 8 (20/43 = 46.5%), 7 (10/43 = 23.2%) and 10 (6/43 = 14.0%). 92.9% (13/14) of the female patients were distributed in the range 7-9 (for the age group 15-25 years). 69.6% (16/23) and 83.3% (5/6) of the male patients were distributed in the range 7-9 for the age groups 15-25 and 26 -35 years, respectively. A total of 78.4% (29/37) of patients were distributed in the 7-9 range for the 15-25 age groups while 83.3% (5/6) were grouped in the same age range for the 26-35 age groups. As for G2, 79.1% (34/43) of patients clustered in the 7-9 range. The absolute scale of pain was modified over time when the treatment was applied with the magnetic field of the electrical network, according to VAS (Table 3). At 20 days of treatment, females were distributed from scales 2 to 0, being remarkable for scale 0 (12/14 = 85.8%) for the age group 15-25 years. The males were distributed from absolute scales 3 to 0, being marked for scale 0, in which 87.0% (20/23) and 83.3% (5/6) of them were concentrated for the age groups 15-25 and 26-35 years, respectively. As for the age group, patients were grouped in absolute scale 0 for 86.5% (32/37) corresponding to 15-25 years and 83.3% (5/6) for 26-35 years. G2 patients were concentrated mainly in absolute scale 0 (37/43 = 86.0%). At 20 days of observation, it was evident from Table 3 from the analysis by VAS range that females in the 15-25 years age group were distributed in 14.3% (2/14) and 85.7% (12/14) in the VAS ranges 1-3 and 0, respectively. However, male patients in the 15-25 age group were located in the VAS 1-3 (3/23 = 13.0%) and 0 (20/23 = 87.0%) ranges while 16.7% (1/6) and 83.3% (5/6) of males in the 26-35 age group were concentrated in these two respective ranges. 13.5% (5/37) and 86.5% (32/37) of the patients in the 15-25 age group were distributed in the VAS 1-3 and 0 ranges, respectively. 16.7% (1/6) and 83.3% (5/6) of patients in the age group 26-35 years were grouped in these two respective VAS ranges. In addition, Table 3 visualized the grouping of G2 patients into VAS ranges 1-3 (6/43 = 14.0%) and 0 (37/43 = 86.0%).[16]

Table 3 Evaluation of pain, 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

experimental groups (No.you)	T$_{obs}$(days)	GE (No.$_{ge}$)	G(N$_g$)	EVE 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		
	fifteen	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
	twenty	15-25 (37)	F (14)									1	1	12
			M (23)								2	1		twenty
		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 by age group and gender, respectively. T$_{obs}$ was the observation time during the application of the magnetic field treatment of the electrical network (G2).

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 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 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.[16,20]

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 magnetic device for the treatment of different pathologies. The software used 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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Conflict of interest

The authors declare that there are no conflicts of interest.

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