

## Possible Effects of Oriented Magnetic Fields on Human Blood Pressure

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### Abstract

**Background:** There have been scattered reports indicating the possibility that applied magnetic fields can lower human blood viscosity, which has been considered as encouraging for decreasing blood pressure as a result of greater fluidity. Additional motivation comes from partial studies in animals showing some response of vascular variables to magnetic fields. Recently developed FeNbB magnets enable topical application to appropriate sites of much stronger permanent magnetic fields than previously available.

**Objectives:** To establish whether powerful magnetic fields permanently applied along important arteries of the human body can lower blood pressure and, if so, to what extent.

**Methods:** Ambulatory blood pressure tests were performed on 70 patients, half of them wearing real magnets, while the other 35 patients were wearing a similar placebo. Magnets or placebo devices were assigned at random. Each patient underwent two consecutive ambulatory 24-hour blood pressure (BP) tests; the first without a device and the second one with a device.

**Results:** Results were compiled and analyzed only after the last measurement was completed. Individual responses, average values, standard deviations, information content, and Student's t test showed that no difference was found between measurements in either group.

**Conclusion:** Permanent strong magnetic fields applied along the main arteries of the human body do not alter blood pressure. This was observed both in statistical terms and in individuals as well.

**Keywords:** Hypertension; Blood Pressure; Magnetic Fields; Heart Disease Risk Factors; Viscosity.

### Background

Hypertension guidelines indicate accurate diagnosis and appropriate therapy with drug treatment.<sup>1</sup> Medication to treat hypertension may have shortcomings, so it would be ideal to have alternative treatments to lower blood pressure (BP) without modifying the natural equilibrium of the body. One example is long-term heated water-based exercises which have a relatively persistence effect.<sup>2</sup> The possibility of achieving similar results by permanently applying external magnetic fields is very attractive.

Early attempts applying magnetic fields to patients reported some positive results,<sup>3-6</sup> but the permanent

magnets used in the past were large in size and weak in intensity. Nowadays, low-cost strong permanent magnets are commercially available.<sup>7</sup>

In vitro measurements using human blood circulating inside glass tubes detected a decrease in viscosity when exposed to oriented magnetic fields:<sup>8</sup> this could lead to increased fluidity and possibly a decrease in BP.

We do not consider other related aspects such as the elasticity of the arteries<sup>9,10</sup> or the effect of the magnetic field gradients on blood cell circulation.<sup>11</sup> Other studies trying to establish the influence of magnetic fields on workers operating magnetic resonance imaging equipment are beyond our line of investigation, since those magnetic fields are inhomogeneous, not

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permanent, and not oriented.<sup>12</sup> In the present study we only address the possible influence of permanent oriented magnetic fields on human BP.

Studies positioning magnets of a few mT (T is for Tesla, the unit of magnetic field) under carotid sinus areas both in rabbits<sup>13</sup> and humans<sup>14</sup> showed some effects on heart rate (HR) and BP.<sup>15</sup> Other studies in rabbits and rats report mild responses to magnetic fields.<sup>16,17,18</sup>

An oral report on the variation of BP in 3 human beings was presented recently.<sup>19</sup> BP measurements decreased in one volunteer after each patient inserted one wrist into the center of an electromagnet (approximately 1.37 T). The exposure lasted for 10 minutes; no statistical work was reported and no additional information has publicly emerged from these experiments.

## Objectives

From previous experiments, the question prevails: Is it possible to significantly lower BP in humans by employing permanently applied magnetic fields? In the present study, we attempt to answer this question utilizing the recently available strong NdFeB magnets.

The main goal is to try to find differences (if any) between measurements in two different groups: one with magnets applied and the other with a similar placebo. A comparative analysis will then be performed at both the individual level and the group level using appropriate statistical techniques.

## Methods

### Data acquisition

All methods involving human participants were carried out in accordance with the Declaration of Helsinki ethical principles. On March 20, 2017, the Ethics Board of the host institution approved the protocol for acquiring and handling the data used in this work. Details about the procedures and members of this board (Comité Ético Científico) can be found at <http://cec.ufro.cl/>. The data used in the present paper correspond to 140 Holter tests conducted between April 2017 and February 2018 on volunteer patients who read and subscribed to the informed consent form approved by the Ethics Board prior to any measurement. The Holter sets were programmed to record vascular variables at intervals

of 15 minutes from 7 am until 11 pm and at intervals of 30 minutes otherwise.

Classifications of stages for hypertension may vary among different regions in the world.<sup>1,20</sup> In the present paper we followed closely the study by Prat et al.<sup>21</sup> Our results involved an ambulatory 24-hour BP monitor (BP Holter), which allows periodic recording of SP, DP, and heart rate (HR). This monitoring system has been in daily use in several countries for decades, using well-established protocols.<sup>22</sup>

Patients came from different origins since this was a public project. Many patients were personnel at the host institution, their relatives, colleagues, friends, and acquaintances. Additionally, about 20% of the patients came in from recommendations of treating doctors. All of them were interviewed by the lead researcher of this project, the procedure was described, the agreement was presented, and the patient signed the informed consent form prior to enrollment.<sup>23</sup> To further protect the anonymity of the patient no track was recorded concerning the origin of the patient's knowledge of the project. The sample comprised 70 adults with an average age of 52 years; 35 of these patients were female (average 53 years), while the remaining 35 were male (average 51 years). None of the patients suffered from any other disease; some of them were on treatment for high BP. The appointment for the tests was established by common agreement with just one constraint: the two tests (without and with the device) had to be done on consecutive days.

Just minutes prior to the second test, a random number was used to decide whether a placebo set or a magnet set was placed on that patient. This was previously unknown to the researcher and it was always unknown to the patient and also to the medical doctor reporting the outcome of the Holter tests. This double-blind procedure was strictly observed until the end of the clinical part of the project. The statistical analysis was only started after the last patient had been measured.

BP measurements were taken automatically by a standard ambulatory 24-hour monitoring system. Instructions were given to the patients to better manage the measurements and they were requested to return to the clinic after almost 24 hours, where the BP monitoring system was removed and the data were downloaded to the computer. Results were included for analysis if they had more than 60 (77 %) valid measurements, with respect to the optimal 78 tests

in a full 24 hours; otherwise the complete procedure was repeated.

The tests were later analyzed and reported by an expert who commented on the data according to standard procedures. The results of the first test (no device) were sent to the patient as a courtesy and the contact with the patient stopped right there.

## Devices

Four sets were prepared: two of them with magnets and two of them with pieces of metal similar to the magnets in appearance and weight. Only the researcher in charge could know which one devices were placebos which one were magnetic. But even this person would be required to consult the computer for the arbitrary 10-digit code number identifying each device to tell the difference. The researcher wrote the code number on the appropriate slot without any relationship to the measurements, which were conducted automatically in her absence. The computer code was designed to produce the same number of magnet and placebo tests in the long run, which was achieved.

Figure 1 illustrates the way the magnetic device was prepared. Two cylindrical magnets with 3 mm diameter and 20 mm length were set in parallel with their magnetization orientations pointing in opposite

directions. These magnets were obtained from Neotexx-Neo magnets (Regattastraße 269, 12527 Berlin, Germany) and according to the manufacturer, they can produce a magnetic field slightly over 1 T just in front of each end.<sup>5</sup> The distance  $d$  between magnet axes was varied until magnetic field lines nearly perpendicular to the axes were produced. The optimal distance  $d$  was found to be 41.5 mm producing a nearly parallel magnetic field between the tips of the two magnets, as illustrated in Figure 1 (left), where fine magnetic sand was dropped on a piece of thin white carton placed over the magnetic device: the field lines can be clearly observed. Then, the system was firmly packed, mounting the magnets in a carved piece of rubber of appropriate dimensions. The magnetic field around the device was later measured at the laboratory of Prof. Juliano Denardin at Cedenna (Santiago) using a Gauss/Teslameter by F.W. Bell, Model 5080. Measurements were taken at 2 mm and 5 mm from an imaginary axis joining the tips of the magnets, yielding 90 mT for the former and 35 mT for the latter. So, on average, the artery (3 to 4 mm away) was exposed to magnetic fields of at least 50 mT, permanently for a period of 24 hours. This is a stronger intensity and a longer exposure than any experiment using permanent magnetic fields reported in the past. The exact value of the magnetic field is not important for the goal of orienting magnetic cells (if any) in the blood.

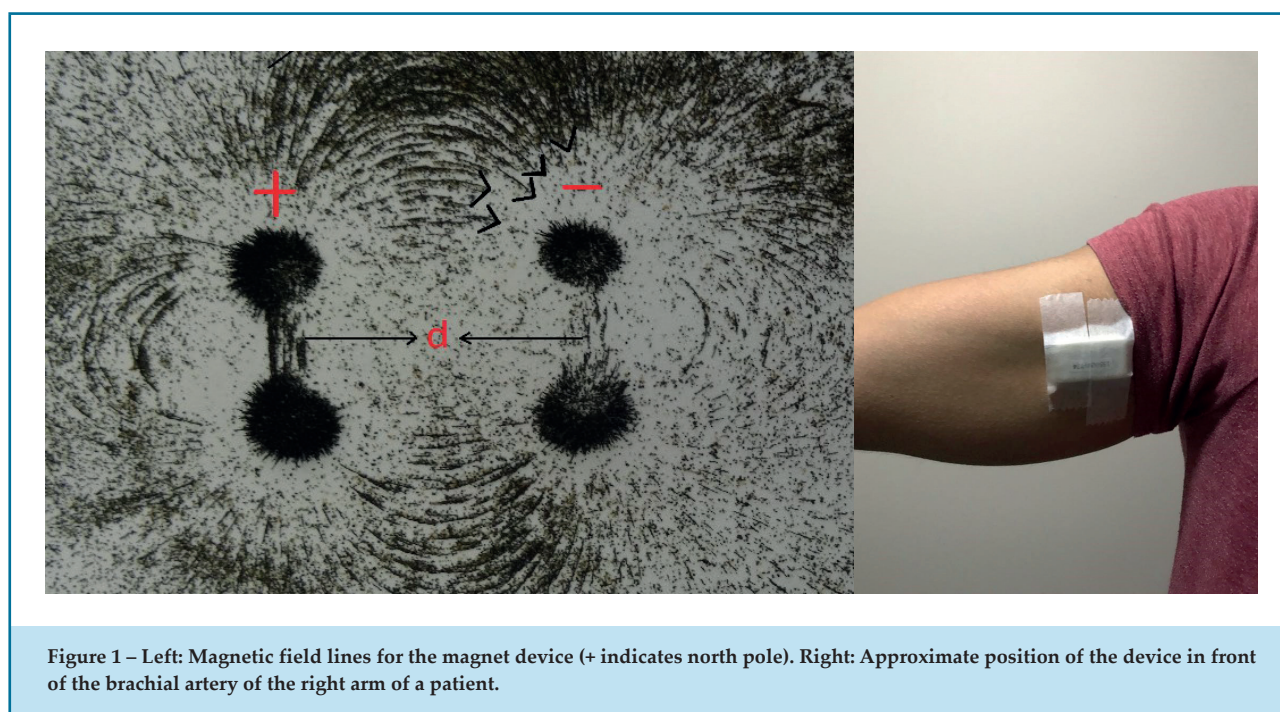


Figure 1 – Left: Magnetic field lines for the magnet device (+ indicates north pole). Right: Approximate position of the device in front of the brachial artery of the right arm of a patient.

Figure 1 (Right) shows the way the device was fitted in front of the brachial artery, close to the armpit, above the BP monitor cuff which was closer to the elbow (the cuff is not shown in the photograph), on the right arm of one of the patients. A similar procedure was performed on the left brachial artery and both femoral arteries. The magnetic field was parallel to each artery and the direction of the field was always towards the extremity of the arm or the leg.

The role of the magnetic field is to establish a North-South orientation magnetic field which can act on any magnetic body present in the blood, thus producing chains of magnetic particles aligned along the artery which could possibly lower the viscosity (illustrations of this effect can be seen in Reference 8). In this way, the cells would align when passing near the device and remain so for a few more cm before gradually disorganizing afterward. This partial longitudinal ordering could possibly lead to decrease in blood pressure. The model corresponds to a ferrofluid where magnetic particles are suspended in liquids.<sup>24</sup> It turns out that they respond to even weak fields since the particles are not fixed to any framework. Stronger fields than those used here could produce magnetic gradients leading to magnetic forces on any magnetic particle present in the blood, which is not a desired effect in the present experiment.<sup>24</sup> Similarly, we are not interested in any phenomena coming from low-frequency oscillatory fields, which is currently the subject of research for different purposes.<sup>25,26</sup> All the magnetic fields used here were constant in time, nearly parallel to the arteries, of about or over 50 mT, and permanently applied to the patient during the entire test.

### Statistical analysis

The files were accessed and handled after all 70 patients had been tested. The patients were arbitrarily numbered from 1 to 35 within each group. These code numbers were preserved throughout the study, but were not related to any individual at any time. The first numerical work is with the Holter test results for each patient. Each data sequence was ordered in vector files, one for each variable: SP, DP, and HR. This was done for each of the two tests of the same patient; averages and standard deviations were obtained. All variables used in this analysis were continuous. Testing for normal distribution of all continuous variables with the Shapiro-Wilk test returned no significant values for any of them.

In consequence, continuous variables were all expressed as means and standard deviations.

In addition to these basic statistics, we also searched for information content within each data vector using the information recognizer *wlzip*.<sup>27</sup> This algorithm finds matches in data chains thus enabling recognition of repetitive pieces of meaningful information. The outcome of this process is a parameter called mutability, which has relatively low values for monotonous sequences and high values for disordered or chaotic series. This information theory technique has been applied previously to study the dynamic variability of stock markets,<sup>28</sup> pension systems,<sup>29</sup> magnetic phase transitions,<sup>27</sup> wind energy production,<sup>30</sup> seismic risks,<sup>31</sup> and BP characteristics.<sup>32,33</sup> In the present study, we follow the general line of this last paper, in which further details about mutability can be found. Results for all these numerical parameters will be given below. Regular Office data sheets were used in the analysis.

Additionally, a Student's *t* test<sup>34</sup> analysis was conducted to search for significant statistical differences between baseline and with-magnet sequences. The paired Student's *t* test was used for the two sets of data within each group. The unpaired Student's *t* test was used to compare data on the same variable from the two different groups. The significance criterion used was 0.05; namely tests on SP, DP, and HR were required to be much larger than this threshold.

### Results

Table 1 shows the baseline characteristics of the two groups. The first column identifies the property, the second column lists the corresponding average baseline results for the placebo group, the third column shows the same for the magnet group, the fourth column gives the Student's *t* test result for the difference in vascular measurements between these two groups, and the fifth column yields the percentage difference between the second and the third columns, as indicated in the caption.

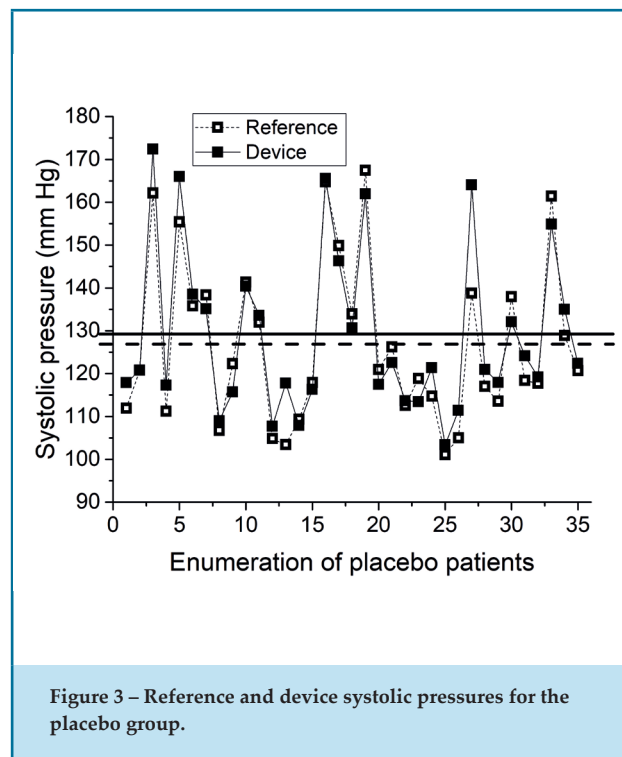
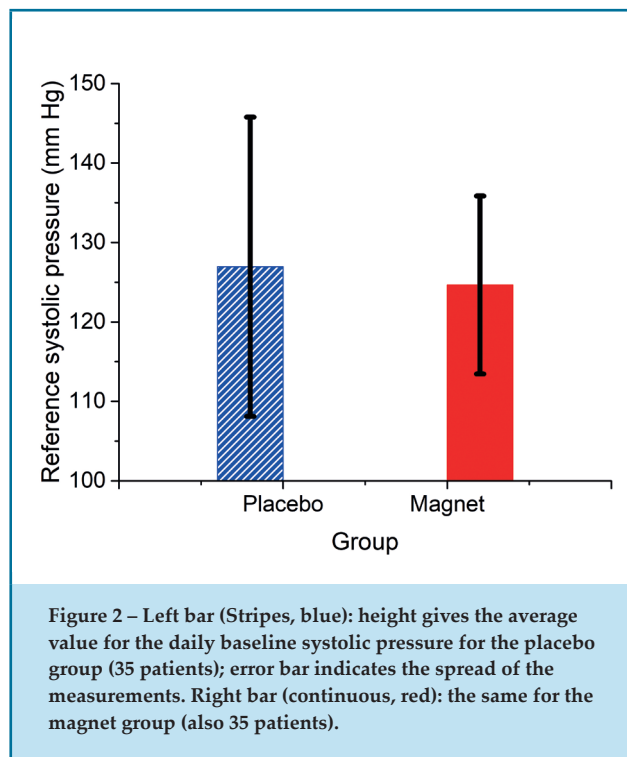
We focus here mainly on systolic pressure which is usually monitored as a possible cause of vascular accidents.<sup>35</sup> Figure 2 shows a comparison of the average baseline SP measurements for the placebo group and the magnet group. Similar plots were obtained for DP and HR.

Figure 3 illustrates the results of the two consecutive systolic pressure measurements for the placebo

**Table 1 – Baseline averages for the 35 patients in each group. Measurements here were made without any device and characterize the initial conditions of both groups.**

Group Averages	Placebo baseline	Magnet baseline	p-value baseline	Percentage baseline
Age (years)	54.8±9.9	49.3±11.6		10.0
Systolic Pressure (SP, mm Hg)	126.9±18.8	124.7±11.2	0.54	1.7
Diastolic Pressure (DP, mm Hg)	76.4±10.9	77.50±8.53	0.64	1.4
Heart rate (HR, 1/min)	69.0±9.4	71.0±8.5	0.37	2.9

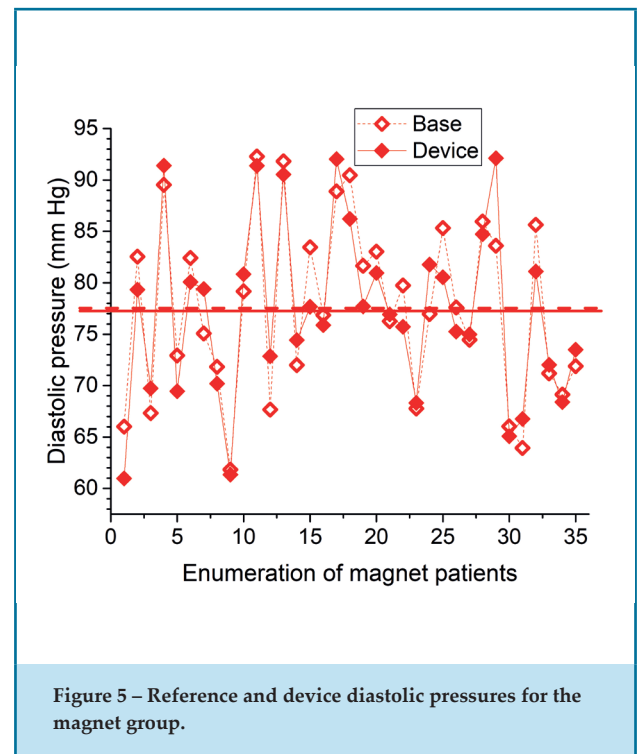
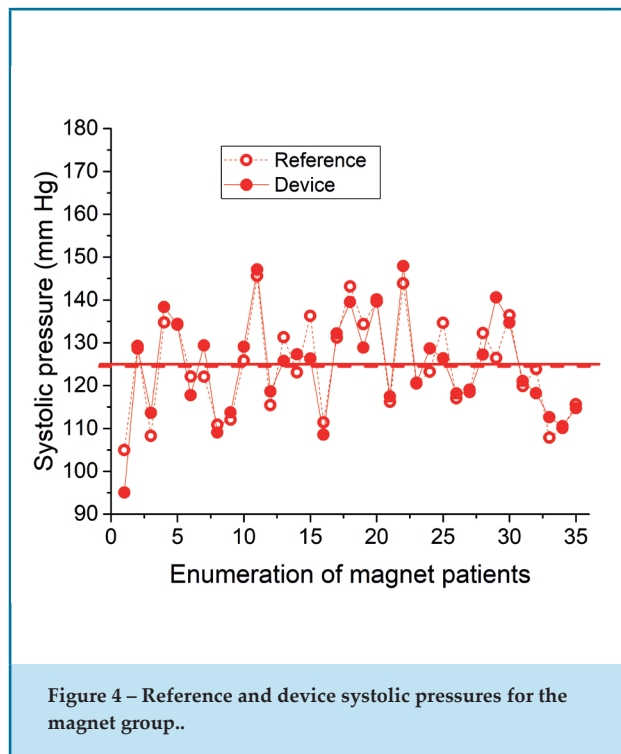
The age difference is slightly noticeable (within error), but has no influence on the other variables, which have negligible differences that are within standard deviations; SP: systolic pressure; DP: diastolic pressure; HR: heart rate. Significance: the p-values for Student’s t test are non-significant. Percentage differences are calculated by means of the following expression: (magnet value-placebo value)/placebo value, and then expressed as a percentage.



patients, whose assigned numbers can be found on the abscissa axis. The corresponding ordinate gives the patient’s average SP for the baseline measurement (open square) and the placebo measurement (solid square). The overall average of baseline average measurements is represented by the dashed horizontal line, while the overall average of the device (placebo) measurements is given by the continuous horizontal line. We do not include error bars in any of the plots, but the average standard deviations are given in the tables.

Figure 4 illustrates the results of the two successive SP measurements for the magnet patients, whose assigned numbers can be found on the abscissa axis. The corresponding ordinate gives the patient’s average SP for the reference (magnet) measurement using an open (filled) circle. The overall average of the reference (magnet) average measurements is represented by the dashed (continuous) horizontal line.

Figure 5 illustrates the results of the two successive DP measurements for the magnet patients, whose assigned numbers can be found on the abscissa axis.



The corresponding ordinate gives the patient's average DP for the reference (device) measurement by means of an open (filled) diamond. The overall average of the reference (magnet) average measurements is represented by the dashed (continuous) horizontal line.

The results with magnet and placebo devices are compiled in Table 2. SP average values changed from  $124.66 \pm 11.20$  to  $124.60 \pm 11.71$  mm Hg with the magnet (NS) and from  $126.94 \pm 18.93$  to  $129.60 \pm 19.03$  mm Hg with the placebo (NS). Changes in Diastolic BP, HR, and mutability were similar (NS) at baseline and after application of the magnet or the placebo. All mutability values oscillate around 2.40 showing no significant differences for either baseline/placebo or baseline/magnet.

In addition, we conducted Student's *t* tests. In particular, this test is particularly relevant to compare the data for the magnet group reference measurements to the data for measurements with the device. Specifically, this comparison is of data from the same patients at two instances, to determine whether there are significant differences between the two measurements. This analysis begins by validating the data distribution for both the placebo and magnet datasets using the Shapiro-Wilks criterion. The criterion was satisfied for SP, DP, and HR in both groups. The Student's *t* test

significance *p*-values are 0.94, 0.52, and 0.53 for SP, DP, and HR respectively, all of which are way beyond the 0.05 threshold commonly used to validate the test.

## Discussion

Despite the independence of both groups, they had initially similar results for the vascular variables as evidenced by Table 1. This is reinforced by Figure 2: the systolic response of these two groups is very similar and the small difference in the average values lies well within the margin of error. Similar analyses hold for the other vascular variables measured by the Holter tests. The second-third and fourth-fifth columns of Table 2 report the values measured for SP, DP, and HR for the placebo and magnet groups respectively. Standard deviations and mutability values for each variable are also reported. These two randomly generated groups show no significant differences in their basic indicators.

There is no significant difference between the two average measurements of SP for the placebo group as shown by Figure 3. This indicates that the device itself does not cause any important deviation in the average SP of the group. It can also be observed that there are no patients with variations larger than the average standard deviation and only very few patients with

**Table 2 – Placebo and magnet groups average results.**

Group averages	Placebo baseline	Placebo device	p-value placebo ←	Magnet baseline	Magnet device	p-value magnet ←	p-value device *
Systolic (SP)	126.94 ±18.83	129.6 ±19.03	0.07	<b>124.66 ±11.20</b>	124.60 ±11.71	<b>0.94</b>	0.25
Mutability (SP)	2.25 ±0.09	2.29 ±0.10		<b>2.18 ±0.11</b>	2.21 ±0.08		
Diastolic (DP)	76.40 ±10.90	77.32 ±11.53	0.22	<b>77.50 ±8.53</b>	77.13 ±8.45	<b>0.52</b>	0.94
Mutability (DP)	2.40 ±0.12	2.44 ±0.10		<b>2.40 ±0.11</b>	2.37 ±0.09		
Heart rate (HR)	69.04 ±9.42	69.19 ±8.23	0.82	<b>70.99 ±8.5</b>	71.37 ±8.6	<b>0.53</b>	0.28
Mutability (HR)	2.19 ±0.16	2.19 ±0.12		<b>2.22 ±0.11</b>	2.21 ±0.12		

*Differences between any column and the Placebo baseline column are all under 5% and have no significance in the present analysis. SP: systolic pressure; DP: diastolic pressure; HR: heart rate. Left arrows (←) indicate that these p-values apply to the values corresponding to the two columns to the left; the asterisk (\*) in the last column indicates that these p-values correspond to the data in the third and sixth columns.*

slight mixed variations. Moreover, the continuous and the broken dashed lines in Figure 3 can be recognized as the same “signature”, even though the abscissa value was randomly assigned. So, not only is the average value of SP preserved, but the individual response with and without the placebo device was also nearly the same.

A similar discussion applies to the average SP of the magnet group, as shown in Figure 4, in that the reference measurements are essentially the same as those obtained when the magnets were on the patient. This applies both to the average values and to the individual values for each patient. If there had been an effect from the magnetic fields, at least two changes would be expected: a general displacement of the curve for the device measurements in Figure 4 to lower values and different responses from different patients, thus significantly altering the “signature” of the continuous line compared to the dashed line in Figure 4. Nothing of the sort happens, so the SP seems to be insensitive to the oriented magnetic fields.

The comments concerning the results reported for the SP are applicable to the DP results illustrated in Figure 5, so no significant changes were obtained after applying the magnetic device.

Entirely equivalent results are found for HR (not illustrated graphically), both for average values and individual values. Additional information on this variable, standard deviations, and mutability values can be found in the tables. All this information points to null effect from the oriented magnetic fields. In addition, Student’s *t* test indicates no effect after application of

magnet devices, as shown by the values exceeding 0.05 reported above.

As is clear from the results and the discussion, we found no significant differences in the measurements with and without magnetic fields, even though the permanent magnets we applied are stronger than any that have been used previously. One possible explanation is that our measurements are extended in time (24 hours of monitoring), which suppresses or inhibits any stress or anxiety effect coming from short tests. Possibly, certain methodological differences, like the way magnets are placed and the way the cardiovascular variables are detected and measured, could also matter.

However, a more basic explanation is also possible: there are no magnetic elements in arterial blood that can be oriented, due to the diamagnetic nature of most of the constituents of human blood.<sup>36</sup>

Further graphical and tabular information was obtained for all the vascular parameters. The corresponding analyses were performed and they further confirmed that magnetic fields in the way proposed here do not affect the vascular variables.<sup>23</sup> This information is not included here for reasons of space, but is available upon request from the corresponding author.

## Conclusions

Permanent magnetic fields of fractions of a Tesla located close and parallel to four of the main arteries

of the human body do not alter the values of the most important vascular parameters of the circulatory system. This holds both for the group measurements and for the individual measurements, within the margin of error.

Higher intensity oriented permanent magnetic fields are difficult to imagine on humans at the moment and there is no reason to believe that any further ordering in the blood circulation could be achieved by longer exposures to oriented magnetic fields. Application of randomly oriented magnetic fields (like exposure of the entire body to a region of inhomogeneous magnetic field) cannot have an ordering effect since the alignment achieved in one sector could be different from the alignment achieved elsewhere.

From what is presently known, application of oriented permanent magnetic fields to the circulatory system causes no significant modification to human blood pressure.

### Author contributions

Conception and design of the research: Eugenio E. Vogel, Benjamín Stockins. Acquisition of data: Nataly Belmar, Benjamín Stockins. Analysis and interpretation of the data: Nataly Belmar, Eugenio E. Vogel, Benjamín Stockins. Statistical analysis: Nataly Belmar, Eugenio E. Vogel.

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### Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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### Study Association

This article is part of the thesis of master submitted by Nataly Belmar Ríos, from Universidad de la Frontera.

### Ethics approval and consent to participate

This study was approved by the Ethics Committee of the of Comitê Ético Científico de la Universidad de la Frontera under the protocol number 13\_2017. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.



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