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Effects of Sinusoidal 0.5 mT Magnetic Field on Leukocyte Adherence Inhibition

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ABSTRACT

Exposure of T lymphocytes to an external 50 Hz and 0.5 mT magnetic field was investigated in vitro using leukocyte adherence inhibition (LAI) assay which is a measure of cell-mediated immunity. Adherence of T lymphocytes taken from healthy humans and from cancer patients before and after medical treatment is enhanced after 1 h exposure to the magnetic field. The experimental findings for the magnetic field 0.5 mT are compared with published data for 1 and 10 mT. The results are consistent with suggestions of magnetic field effects on immune function in humans.

Key Words: Biological effects of magnetic field; Cell adherence inhibition; Cell-mediated immunity.

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INTRODUCTION

Adherence properties of leukocytes (prepared from peripheral blood) are considered to correlate with cell-mediated immunity. An in vitro quantitative technique widely used to monitor cell-mediated immunity is the leukocyte adherence inhibition (LAI) assay based on observation of adherence of leukocytes to solid state substrates in the presence or absence of antigens (Gipson and Martin, 1978; Grosser and Thomson, 1975; Halliday and Miller, 1972; Hellströem et al., 1976; Holáň et al., 1974; Koppi et al., 1979; Marti and Thomson, 1976; Noonan et al., 1977; Shani et al., 1978; Tataryn et al., 1978; Thomson et al., 1979) (an overview is in Jandová et al., 2001). The antigen is bound to its corresponding receptor in the plasma membrane and consequently changes the cell adherence properties. Adherence properties of leukocytes can be changed by other chemical and physical agents. Magnetic field is one of the physical agents that are capable of changing leukocyte behavior (Binhi, 2002; Milani et al., 2002).

We have to overview biochemical mechanisms that could influence adherence on the leukocyte membrane. We have studied the membrane response of human T lymphocytes to antigen prepared from blood taken from inbred mice ($C3H/H^2k$) infected with lactate dehydrogenase-elevating virus (LDV) (Jandová et al., 1989a) as a model of alteration of the cell-mediated immunity. The influence of magnetic field on envelope protein(s) of lactate dehydrogenase-elevating virus and the T lymphocyte membrane topography of receptors is very likely the most significant point for explanation of the binding system of the immune complex between antigens and antibodies in vitro (Faaberg and Plagemann, 1995). The effect of LDV antigen is compared with the effects of antigens prepared from human cancer tissues (Jandová et al., 1989b).

The lactate dehydrogenase-elevating virus belongs to a new family of positive-strand RNA viruses (presently classified as genus Arterivirus). The genome organization and the replication strategy of this virus are similar to those of the coronaviruses, but the size of the genome of the LDV (12–15 kb) is only about one half the size of that of the coronaviruses. The virions possess an envelope and a spherical nucleocapsid and are 50–60 nm in diameter (Li et al., 1998).

Three major structural proteins have been identified for this virus: a 13–15 kDa nucleocapsid protein (N/VP-1), a 18–20 kDa nonglycosylated envelope protein (M/VP-2), and a primary envelope glycoprotein (VP-3, G_L or E) that is generally heterogenous in size varying from 25 to over 40 kDa. Neutralizing monoclonal antibodies (mAbs) to LDV have been shown to be directed to VP-3 (Godeny et al., 1990).

Interaction with the nucleocapsid composed of the genomic RNA and the nucleocapsid protein (N/VP-1, encoded by ORF 7—Open Reading Frame) has an important role in the maturation of virion particles. Free LDV nucleocapsid is known to be formed in the cytoplasm of LDV-infected macrophages (according to our experimental investigation about 1/3 of the human population in the Czech Republic was infected by LDV; the data in other countries might be similar). The genome of LDV is a single-stranded RNA molecule of positive polarity, which contains a poly(A) tract at its 3 terminus. The estimated molecular weight of the genome is 5×10^6 Da (Godeny et al., 1990).

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The neutralization epitope of lactate dehydrogenase-elevating virus and its location on the short ectodomain of the primary envelope glycoprotein were described by Li, Chen, and Plagemann (1998). The anti-LDV antibodies are primarily of IgG2a, IgG2b, and IgG3 isotype and directed to the primary envelope glycoprotein (VP-3P), the nucleocapsid protein (N/VP-1), and ORF 3 protein (Li et al., 1998).

Recent studies have shown that an 8-kDa protein is membrane associated and that small amounts of it are recovered in purified virions. It is known that the 8 kDa protein is another arterivirus envelope protein and is designated as E protein. Plagemann (2001) has not detected a significant level of an 8-kDa protein in LDV virions and concluded that it is not a structural virion component. The 8-kDa protein seems to be associated with ER/Golgi membranes (Plagemann, 2001). LDV-induced autoantibodies directed against antigens of the Golgi apparatus have been observed (Weiland et al., 1990).

Susceptibility to immune response is a property of LDV antigen, correlated to the number of n-linked polygalactosaminoglycan chains on the ectodomain of the primary glycoprotein envelope. VP-3P is probably part of the attachment site for the LDV receptor on permissive cells (Chen et al., 1998).

The effect of glycocorticoids on the expression of cellular and of retroviral dexamethasone genes may function by inducing the expression of a protein(s) in macrophages required for aproductive LDV infection, for instance a surface LDV receptor at the CD_4 membrane. For example, dexamethasone alters the expression of the beta-glucan receptor as a donator of energy, and can participate in LDV binding to macrophages (Cafruny et al., 2003).

Lawrence (1954) confirmed in 1954 that transfer of the cell-mediated immunity by human cells is not only active but also passive by means of dead cells and their homogenates. In 1963 he proved that low-molecular mass factors (10,000 Da) are responsible for this passive transfer. This low-molecular mass fraction may contain viral infectious agents. This ''transfer factor'' causes many changes of the cell-mediated immunity (e.g., formation of rosettes with sheep erythrocytes) (Lawrence, 1954; Lawrence et al., 1963).

Above we have described a possible area on the membrane for the action of the LDV antigen. Energy sources for immunological and genetical reactions in living cells however are not exactly determined. Study of the effects of sinusoidal 50 Hz magnetic field on leukocyte adherence can help to explain some macromolecular interactions.

Immunological information may also depend on energy levels of the states above the thermodynamic equilibrium and interactions among them. A possible mechanism based on excitation of polar vibration states and their coherence was postulated by Fröhlich (1969). Measurements of such coherent vibration states are only now beginning and are mainly focused on photosynthetic systems (Vos et al., 1993, 1998) or certain biological molecules (Vos et al., 2000). The energy source for processes included in adherence and its changes has not been analyzed yet. Cells with high energy consumption and/or with low energy level may behave differently from normal cells at physiological levels (Pokorný and Wu, 1998). Maroudas revealed a dependence of adherence and spreading of cells above a solid state surface on its surface charge (Maroudas, 1975, 1977). We have elsewhere assumed that a field

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of electromagnetic origin participates in adherence (Pokorný et al., 1996). Magnetic field effects may help in understanding the adherence energy mechanisms.

The influence of magnetic fields on human lymphocytes was recently studied, for example in (Aldinucci et al., 2003; Marshevich et al., 2003). The effect of 50 Hz magnetic fields and of the known aneugen vinblastine (VBL) on micronucleus formation was tested with the in vitro cytokinesis block micronucleus assay in human lymphocyte cultures. An effect of 50 Hz magnetic fields and of vinblastine on the nuclear division index (NDI) and on apoptosis was observed (Verheyen et al., 2003) with a drastic decrease in NDI.

LAI assay was used for study of the effects of magnetic field (50 Hz, 1 and 10 mT) on T lymphocytes in (Jandová et al., 2001). After exposure to the 1 mT magnetic field the number of adherent T lymphocytes taken from healthy humans decreased. In contrast, the number of adherent T lymphocytes from cancer patients increased. The reverse effects of the magnetic field 1 mT on adherence properties of T lymphocytes taken from healthy humans and cancer patients suggested that the effects of magnetic fields smaller than 1 mT on adherence should be studied. If the mechanisms of action of the magnetic field are the same in both cases then dependence of the adherence on the field should be similar, but quantitative differences might exist. Therefore, exposure of T lymphocytes to magnetic fields smaller than 1 mT may bring significant results. The threshold value of induction of the magnetic field below which the effects are not observable is another important point as one studies how the magnetic field alters the immunity function of T lymphocytes.

Study of the effectiveness of the antigens under different magnetic field intensities is important for understanding and assessment of their action. The other important point is the time development of the immunological response of T lymphocytes taken from cancer patients before and after medical treatment together with the exposure to the magnetic field.

MATERIALS AND METHODS

The T lymphocytes were prepared from venous blood of healthy humans and cancer patients before and after medical treatment. We used blood taken from patients with otorhinolaryngological tumors (carcinoma pharyngis). Histopathological verification of cancer was diagnosed. Medical treatment included surgery and chemotherapy. The first group of cancer patient before and after medical treatment did not contain the same patients ($N = 33$). The most recent group of cases examined before and after medical treatment contains the same patients ($N = 32$). The mean time of the LAI assay investigation was 10.2 months after medical treatment. For purification of T cells a syringe filled with nylon absorbent wool was used as a filtration column. The filtered pool contained about 92% of T cells and 8% of other cells (Tlaskalová-Hogenová et al., 1980). A detailed description of preparation of T lymphocyte cells is found in Jandová et al. (2001).

Specific antigen was an immunoactive fraction prepared from a malignant tumor of the same type as that of the patient the blood was taken from. Organs with cancer were taken during surgery. Nonspecific antigen was an immunologically functional fraction prepared from the serum of inbred laboratory mouse strain C3H

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infected with the virus (LDV) enhancing the lactate dehydrogenase isoenzyme. Antigen was mixed with the suspension just before exposure to the magnetic field at a ratio of 1 part of antigen to 4 parts of T cell float. A comprehensive description of the preparation methods of the antigens is given in Jandová et al. (2001).

Suspension of T cells in the test tubes from green Sial glass was positioned in the center of a coil generating magnetic field. Exposure time was 60 min allowing us to compare the results after exposure to the magnetic field with the standard LAI assay results. The test tubes of the sham experiments without exposure to the magnetic field were positioned in the same coil but with no magnetic field just after the exposed experiment ended (i.e., after 60 min). In the meantime the sham test tubes with suspension were refrigerated at about 3°C (the time delay does not cause significant differences in results in comparison with those measured immediately after preparation of the cell suspension; See Fig. 1 and Table 1). The antigens were given in the test tubes with suspension just before they were positioned into the coil. The measurement method is described in detail in Jandová et al. (2001).

The coil-producing magnetic field is 30 cm in diameter and 33 cm in length. The axis of the coil is oriented vertically. Magnetic induction was measured by the magnetometer (Gauss/Teslameter) Sypris (F.W. Bell, Orlando, FL, USA) model 7030, with Hall probes (accuracy in dc mode to 250 Hz is 0.05% of reading, in ac mode ±2%). Magnetic induction was also measured by a magnetometer (EFA3 Wandel & Goltermann Eningen, Germany) with three coils and by a small coil connected to a millivoltmeter and to an oscilloscope to determine the waveform and harmonic distorsion. The amplitude of the induction was determined from the RMS values measured by the magnetometer Sypris with Hall probes assuming sinusoidal waveform. The values of 8.7, 0.9, and 0.46 were denoted as 10, 1, and 0.5 mT,

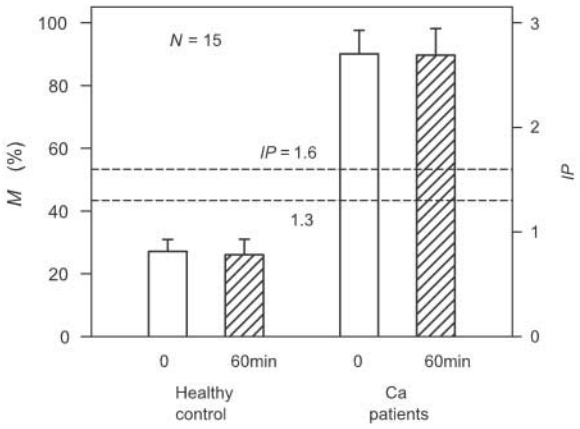


Figure 1. The mean value of the number M (in per cent) of nonadherent T lymphocytes taken from healthy humans ($N = 15$) and cancer patients ($N = 15$) without exposure to the magnetic field measured immediately after preparation of the suspension with the T lymphocytes and 60 min later (during the 60 min period the suspension was stored in the dark at 3°C). The differences in adherence are not statistically significant as follows from Table 1. Vertical bars denote standard deviations.

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Table 1. Significance level p of the mean value of the number M of nonadherent T lymphocytes measured immediately after preparation of the suspension with cells and 60 min later (with no exposition to the magnetic field). H and CaB denote groups in which the T lymphocytes were taken from healthy humans ($N = 15$) and cancer patients ($N = 15$) before medical treatment, respectively. Wilcoxon rank test for two dependent groups was used.

	Groups	
Time (min)	H × H	Ca × Ca
	WR	
0 × 60	0.0937	0.6289

respectively. The values of the amplitude of the magnetic induction measured by Hall probes are about 10% smaller than those measured by systems with small coils. The differences may be caused by the distorted waveform of the induction and by higher harmonic components as the voltage induced in a coil is proportional to the frequency of the magnetic induction. The static magnetic field (the Earth field) was 46 μT in the room near the coil generating magnetic field and 42 μT inside the coil.

The number of nonadherent T cells in suspension was counted after 60 min of exposure to the magnetic field and without any exposure to the magnetic field. The results of the LAI assay can be expressed as a relative number of nonadherent cells M (in percent), as a nonadherence index, NAI, and as an index of positivity IP. The nonadherence index NAI is given by the relation (Grosser and Thomson, 1975)

$$\mathrm{NAI} = \frac{(M_S - M_N)}{M_N} \times 100,$$

where M_S and M_N are the number of nonadherent T cells in the presence of the specific and of the nonspecific antigen, respectively. To simplify assessment of the LAI assay a normalized value of M given by the relation $\mathrm{IP} = M/A$ where $A = 100/3$ was introduced (with three significant values—1, 1.3, and 1.6) to assess malignant processes in humans (Jandová et al., 2001). The magnitude of the constant A provides that most of the LAI assay cases for lymphocytes taken from cancer patients with specific tumor antigens are above $\mathrm{IP} = 1$ (99.4% of cases). The majority of IP values for lymphocytes taken from healthy humans satisfies relation $\mathrm{IP} \leq 1.6$ (also about 99.4%). For practical reason the level $\mathrm{IP} = 1.3$ is used too. We found from a long-term statistical evaluation of LAI assay results (Jandová et al., 2001) that a healthy human (a cancer patient) has $\mathrm{IP} < 1.3$ ($\mathrm{IP} > 1.6$) for 95.3% (95.6%) of cases. The "noise region" is for the index of positivity $1.3 \leq \mathrm{IP} \leq 1.6$.

Evaluation of statistical significance was carried out using two-group t-test (TGt), matched t-test (Mt), and one-way analysis of variance (ANOVA) (F statistics was used to prove the normal distribution). These tests are, respectively, for two independent, for two dependent, and for more than two independent sets. The normal distribution is not demanded by the nonparametric tests. We used

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the Mann–Whitney rank-sum test (MWRS), the Wilcoxon rank test (WR), and the Kruskal–Wallis one-way analysis (KWA). We verified the hypotheses that there is no difference in magnitude of the examined parameter (i.e., of M or NAI) (a) in different groups (i.e., in groups of T lymphocytes taken from healthy humans—H, cancer patients before medical treatment—CB, and after medical treatment CA), (b) for different values of the induction of the magnetic field (i.e., 0, 0.5, 1, and 10 mT), and (c) for the same induction of the magnetic field in different groups.

EXPERIMENTAL RESULTS

We conducted lengthy studies on the capability of T lymphocytes to preserve adherence properties in the suspension. We found that under convenient conditions the adherence properties are not significantly changed over a span of time shorter than about 2 h. For instance, Fig. 1 shows mean values and standard deviations of the number M of nonadherent T lymphocytes taken from healthy humans and from cancer patients with no exposure to the magnetic field. LAI assay was performed immediately after the suspension with cells was prepared (the white columns) and after the 60 min interval during which the suspension was kept in the dark at 3°C (the hatched columns). Statistical evaluation of the results is shown in Table 1 (WR). No statistically significant differences at the 0.05 level were found in the adherence of T lymphocytes taken from healthy humans and cancer patients measured immediately and after a 60-min delay.

We investigated the effects of exposure to the 0.5 mT magnetic field on T lymphocytes taken from healthy humans and cancer patients before and after medical treatment. Mean values and standard deviations of the NAI, of the number M of nonadherent T cells, and of the index of positivity IP are plotted in Figs. 2–4. Statistical evaluation of the significance of the results is given in Tables 2 and 3. We describe the experimental results for individual groups and assess the main effects of the exposure to the magnetic field.

Experimental results for T lymphocytes taken from healthy humans are plotted in Figs. 2a and b. Without exposure to the magnetic field the majority of T cells adhere (NAI = 6, $M = 31\%$) whereas exposure to the 0.5 mT magnetic field increases adherence (NAI = 4, $M = 21\%$). Statistical significance $p = 0.0004$ (WR, Table 2, $N = 33$). Exposure to higher magnetic fields than 0.5 mT causes an increase in the number of nonadherent cells (for 1 and 10 mT, M is 54 and 60%, respectively). The data for the magnetic field 1 and 10 mT are taken from Jandová et al. (2001). The mean values of M without exposure and with exposure to 0.5 mT in comparison with those with exposure to the magnetic field 1 and 10 mT are statistically significant at $p \leq 0.0001$, MWRS, (Table 2).

Figures 3a and b show adherence data of T lymphocytes taken from cancer patients before any medical treatment. The mean values of M (NAI) are 84% (15%) (Jandová et al., 1989a) without exposure and 44% (8%) (Marti and Thomson, 1976) with exposure to the 0.5 mT magnetic field (Figs. 3a, b, $N = 33$). Statistical significance $p = 0.0000$ (WR, Table 2). The majority of cells do not adhere and exposure to the magnetic field 0.5 mT increases the number of adherent cells. The mean values of M for 1 and 10 mT are greater than those for 0.5 mT (after

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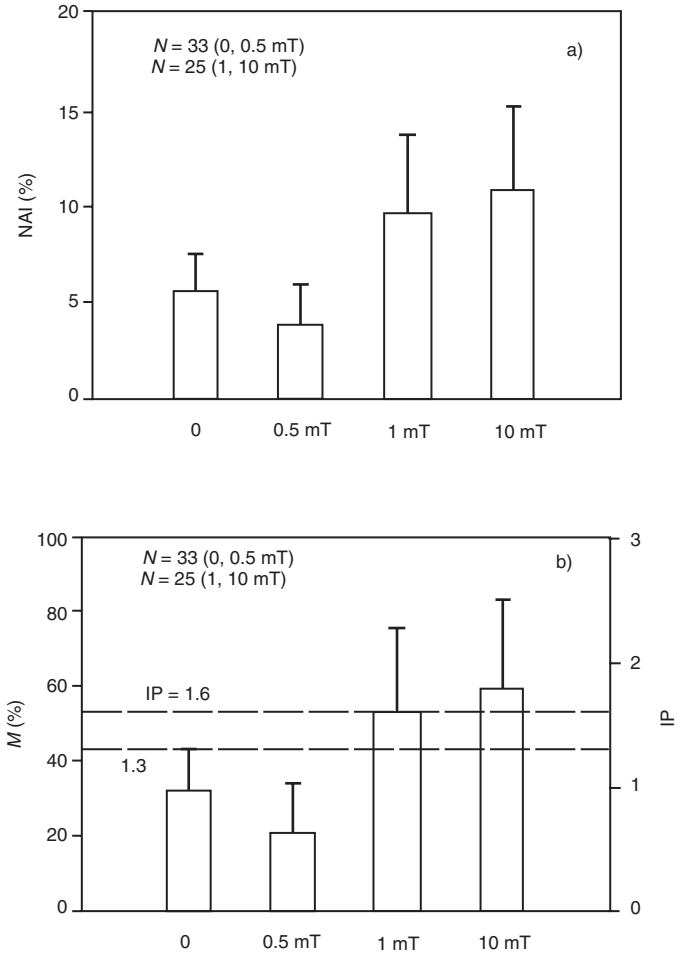


Figure 2. Adherence of T lymphocytes taken from healthy humans without and with exposure to the magnetic field ($B = 0$ and 0.5 mT, $N = 33$). Mean value of the NAI in percent (a) and of the number M of nonadherent cells in percent (b). Vertical bars denote standard deviations. IP—normalized value of the number of nonadherent cells is plotted on the right-hand side vertical axis (b). The dashed lines denote IP = 1.3 and 1.6. NAI and M values for the exposure to the magnetic field 1 and 10 mT are from Jandová et al. (2001) ($N = 25$). Exposure to the magnetic field 0.5 mT increases the number of adherent T cells. Increase of the magnetic field from 0.5 to 1 mT and higher causes decrease of adherence of T cells. Statistical significance is in Table 2.

Jandová et al., 2001) but there is no statistical significance for these differences (Table 2 , MWRS).

Figures 4a, b, and c show the mean values of NAI and of M for T lymphocytes taken from healthy humans and from cancer patients before and after medical treatment. The results in cancer patients before and after medical treatments (Figs. 4a–c) are consistent. Variations of adherence of T lymphocytes in both groups

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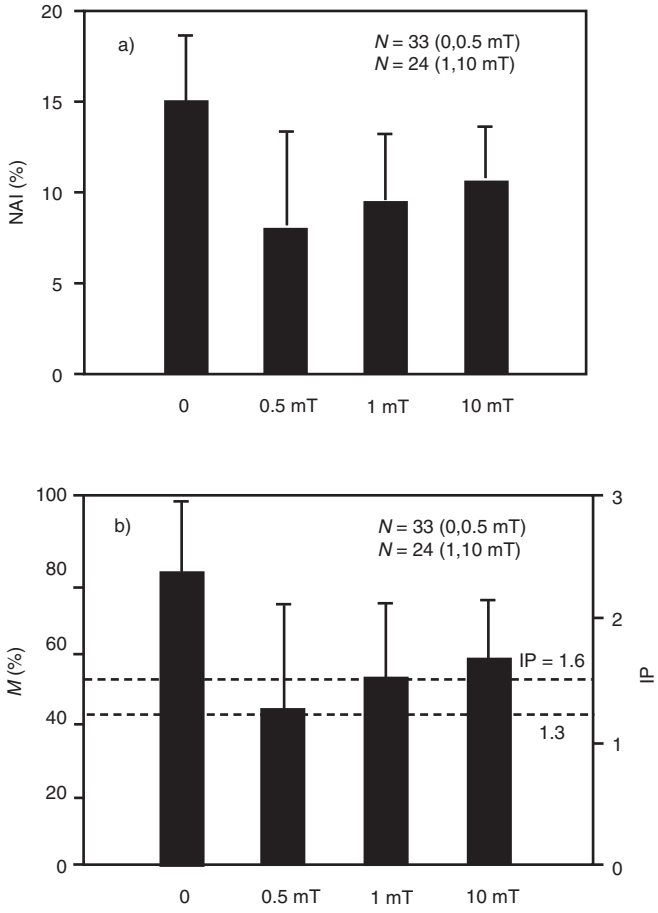


Figure 3. Adherence of T lymphocytes taken from cancer patients before any medical treatment without and with exposure to the magnetic field ($B = 0$ and 0.5 mT, $N = 33$). Mean value of the NAI in percent (a) and of the number M of nonadherent cells in percent (b). Vertical bars denote standard deviations. IP—normalized value of the number of nonadherent cells is plotted on the right-hand side vertical axis (b). NAI and M values for exposure to the magnetic fields 1 and 10 mT are from Jandová et al. (2001) ($N = 24$). Exposure to magnetic field 0.5 mT increases the number of adherent T cells. The difference is statistically significant (Table 2). Decrease of adherence of T cells after increase of the magnetic field from 0.5 to 1 mT and to 10 mT is not statistically significant (Table 2).

are similar, in agreement with the assumption that changes in adherence before and after medical treatment and effects of the magnetic field are general properties. Exposure to the magnetic field increases adherence of T lymphocytes. The mean values of M taken before medical treatment without and with exposure to the magnetic field 0.5 mT are 84 and 44% (b), or 93 and 49% (c), respectively. After medical treatment the corresponding mean values of M are 40 and 24% (b), or 37 and 23% (c), respectively. The differences are statistically significant as follows from

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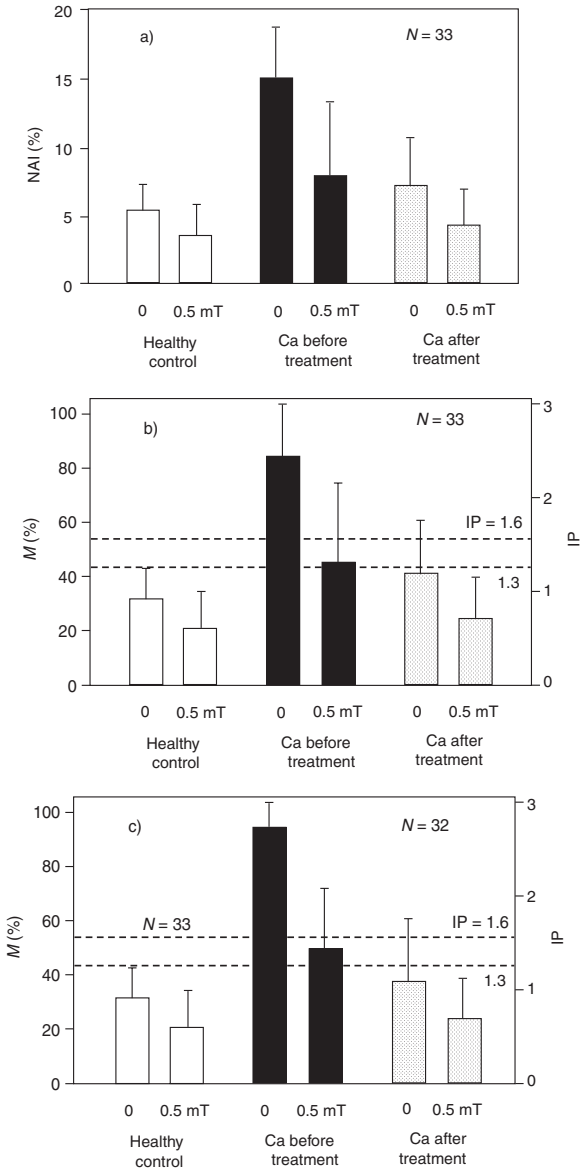


Figure 4. Comparison of adherence of T lymphocytes taken from healthy humans, cancer patients before any medical treatment, and cancer patients after medical treatment without and with exposure to the magnetic field ($B = 0$ and 0.5 mT). Results in cancer patients in the groups before and after medical treatment are different. (a) Mean value of the NAI in percent and (b) in the number M of nonadherent cells in percent. Cancer patients in the groups before and after medical treatment are different (a, b) and the same (mean value of the number M of nonadherent cells (c)). IP—normalized value of the number of nonadherent cells is plotted on the right-hand side vertical axis (b, c). The number of adherent T lymphocytes after exposure to the magnetic field 0.5 mT increases in all measured groups. Statistical significance of the results is in Tables 3a, b .

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Table 2. Significance level p of the mean value of the number M of nonadherent leukocytes without exposure (0 mT) and with exposure to the magnetic field 0.5, 1, and 10 mT determined by the Mann–Whitney rank-sum test (MWRS), by the Wilcoxon rank test (WR), and by the Kruskal–Wallis one-way analysis (KWA). H and CaB denote groups in which T lymphocytes were taken from healthy humans and cancer patients before medical treatment, respectively. The significance levels of M and of NAI are similar.

Magnet. field (mT)	Statist. method	H × H p	CaB × CaB p	H × CaB p	H × H × H p	CaB × CaB × CaB p
0	MWRS			0.0000		
0.5	MWRS			0.0005		
1	MWRS			0.7942		
10	MWRS			0.6026		
0 × 0.5	WR	0.0004	0.0000			
0 × 1	MWRS	0.0001	0.0000			
0 × 10	MWRS	0.0000	0.0000			
0.5 × 1	MWRS	0.0000	0.1871			
0.5 × 10	MWRS	0.0000	0.0178			
1 × 10	MWRS	0.2161	0.5081			
0 × 1 × 10	KWA				0.0000	0.0000
0.5 × 1 × 10	KWA				0.0000	0.0658

Tables 3a, b (in all cases $p < 0.01$, Mt and WR). The data for T lymphocytes taken from healthy humans are the same as in Figs. 2 and 3. The mean values of M for T lymphocytes taken from cancer patients before medical treatment in comparison with those for T cells taken after medical treatment are statistically significant at least at $p < 0.01$ (Mt, WR in Tables 3a, b).

DISCUSSION

LAI assay was used to study the effect of the magnetic field 0.5 mT on adherence properties of T lymphocytes taken from healthy humans and cancer patients before and after medical treatment. We investigated different cancer patients before and after medical treatment as well as the same patients. A magnetic field of 0.5 mT increases the number of adherent leukocytes taken from healthy humans as well as those taken from cancer patients. The tendency to increased adherence does not depend on the stage of cancer development—whether the T lymphocytes are taken before or after medical treatment. We do not know yet the threshold value of the magnetic field that elicits this effect. Increase of the magnetic field from 0.5 to 1 and to 10 mT decreases the number of adherent leukocytes (but the decrease is statistically significant only for T lymphocytes taken from healthy humans). The weaker magnetic field has greater effects on adherence than the stronger fields. The mean values of NAI and of M for T lymphocytes taken from cancer patients before any medical treatment are dispersed in a wider range for 0.5 mT than those for 1 and 10 mT as is reflected in the standard deviation values. Binhi (1997, 1998, 1999, 2000,

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Table 3. Significance level p of the mean value of the number M of nonadherent T lymphocytes with no exposure (0 mT) and with exposure to the magnetic field 0.5 mT. H, CaB, and CaA denote groups in which T lymphocytes were taken from healthy humans and cancer patients before and after medical treatment, respectively. (a) Cancer patients before and after medical treatment were different. Significance level was determined by the two-group t-test with Bonferroni corection, by the matched t-test, and by the one-way analysis of variance (ANOVA). The significance levels of M and of NAI are similar. (b) Cancer patients before and after medical treatment were the same. Significance level was determined by the Mann–Whitney rank-sum test (MWRS), by the Wilcoxon rank test (WR).

(a) Magnet. field (mT)		Groups						
		H × H	CaB × CaB	CaA × CaA	H × CaB × CaA	H × CaB	H × CaA	CaB × CaA
			Mt		ANOVA		TGt	
0	p				0.0000	0.001	0.0283	0.001
0.5	p				0.0000	0.001	0.5442	0.01
0 × 0.5	p	0.0000	0.0000	0.0000				
(b) Magnet. field (mT)		Groups						
		H × H	CaB × CaB	CaA × CaA	H × CaB	H × CaA	CaB × CaA	
			WR		MWRS		WR	
0	p				0.0000	0.5030	0.0000	
0.5	p				0.0000	0.4698	0.0003	
0 × 0.5	p	0.0004	0.0000	0.0015				

2002b) and Binhi and Goldman (2000) explain the primary physical mechanism of interaction of magnetic field with biological system as a mechanism of dissociation of the ion–protein complexes. Magnetic fields might change the quantum states of the ions and their probabilities to dissociate from proteins. The reverse action of weak and strong magnetic fields should correspond to the increase and to the decrease of the dissociation probabilities of the ions. Nonetheless, the mechanism explaining the effects of magnetic fields is not yet clear, for example, other possible explanations may include production of heat shock proteins or changes of excited states in cells. A more detailed description of possible mechanisms is found in Jandová et al. (2001).

Dependence of the adherent properties of T lymphocytes on the magnetic field has a similar form for leukocytes taken from healthy humans and for those taken from cancer patients before and after medical treatment. This suggests that the mechanism of action of the magnetic field does not depend on the malignant process and very likely represents a general effect on the immune system. The main difference is in the adherence of T cells without magnetic field—the majority of T cells taken from healthy humans and cancer patients after medical treatment adheres but that from cancer patients before medical treatment do not adhere.

The specific and the nonspecific (LDV) antigens were used. The effects of both antigens are similar.

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CONCLUSIONS

In the presence of antigen, T lymphocytes taken from healthy humans as well as those from cancer patients before and after medical treatment exhibit a statistically significant increase of adherence after exposure to a 0.5 mT magnetic field as compared with no magnetic field exposure. As the adherence properties of T lymphocytes are considered to correlate with the cell-mediated immunity, the LAI assay results presented in this article suggest that a 50 Hz and 0.5 mT magnetic field has an effect on immunity function in humans.

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