Permanent magnetic field, direct electric field, and infrared to reduce blood glucose level and hepatic function in *mus musculus* with diabetic mellitus

Suhariningsih¹*, Hari Basuki Notobroto², Dwi Winarni³, Saikhu Achmad Hussein³ and Tri Anggono Prijo¹

¹Department of Physics, Faculty of Science and Technology, Airlangga University, Surabaya, Indonesia
²Faculty of Public Health, Airlangga University Surabaya, Indonesia
³Department of Biology, Faculty of Science and Technology, Airlangga University, Surabaya, Indonesia

*corresponden email address: suhariningsih@fst.unair.ac.id

Abstract. Blood contains several electrolytes with positive (cation) and negative (anion) ion load. Both electrolytes deliver impulse synergistically adjusting body needs. Those electrolytes give specific effect to external disturbance such as electric, magnetic, even infrared field. A study has been conducted to reduce blood glucose level and liver function, in type 2 Diabetes Mellitus patients, using Biophysics concept which uses combination therapy of permanent magnetic field, electric field, and infrared. This study used 48 healthy mice (*mus musculus*), male, age 3-4 weeks, with approximately 25-30 g in weight. Mice was fed with lard as high fat diet orally, before Streptozotocin (STZ) induction become diabetic mice. Therapy was conducted by putting mice in a chamber that emits the combination of permanent magnetic field, electric field, and infrared, every day for 1 hour for 28 days. There were 4 combinations of therapy/treatment, namely: (1) permanent magnetic field, direct electric field, and infrared; (2) permanent magnetic field, direct electric field, without infrared; (3) permanent magnetic field, alternating electric field, and infrared; and (4) permanent magnetic field, alternating electric field, without infrared. The results of therapy show that every combination is able to reduce blood glucose level, AST, and ALT. However, the best result is by using combination of permanent magnetic field, direct electric field, and infrared.

1. Introduction

The aim of this research is to determine the best combination of permanent magnetic field with an electric field and infrared for lowering blood sugar levels as well as ALT and AST in mice with type I diabetes mellitus.

1.1. Interaction of magnetic field, electric field, and infrared in the body

Blood in the body contains a variety of electrolytes, such as sodium (Na⁺), potassium (K⁺), calcium (Ca²⁺), Magnesium (Mg²⁺), chloride (Cl⁻), HCO₃⁻, SO₄²⁻, and so on. Both types of these electrolytes (cations and anions) work together to deliver impulses as required by the body. Electrolytes will have certain effects when external disruption of electric and magnetic field is given.
Exposure of external electric field to the body will cause the rearrangement position of free ions in the blood vessels. Negative ions will tend to move in the opposite direction to the direction of the external electric field, while the positive ions will move in the direction of an external electric field that allows collision with negative ions. The interaction of positive ions and negative ions to move due to a disturbance of external electric fields on the body causes electronic polarization be $P = \varepsilon_0 \chi S$, so there will be a potential difference of polarization $V(t)$. Potential polarization that appears will be countered by the potential immune $L(t)$ of the body, so that in healthy individuals, the balance of potential is $G(t) = 0$ (see figure 1). On the contrary, if the body is sick, the potential immune of the body cannot restore or is against the potential polarization formed by the external electric field, so that it results in $G(t) \neq 0$.

![Figure 1](image1.png)

**Figure 1.** External electric field that goes inside the body

Electronic polarization will cause an electric shift with vector density of $D = \varepsilon_0 (1 + \chi) S$. Electric shift that occurred resulted in changes in the refractive index of the cell that satisfies the equation $n_e(S) = n_e - \frac{1}{2} n_e \chi_{33} S$. The changes of refractive index that occur will increase the permeability of the cell plasma membrane, resulting in the increased flow of ions and water through the plasma membrane. The flow of ions and water would lead to changes in the relative conductivity of the plasma membrane.

The relationship between electric field, refractive index, and permeability is also expressed by Saleh and Theich [1], that is the exposure of electric field on the body will reduce or affect refractive index, that is, increasing the permeability of the plasma membrane particularly the lipid group.

Blood (containing iron ferromagnetic) is also regarded as magnetic materials which has paramagnetic properties. When given the disruption in the form of an external magnetic field, the molecules in the blood cells will align with the direction of the external magnetic field is given as shown in Figure 2, although only temporarily because the orientation of the molecules that is subject to interference will return to its original position when external magnetic field is eliminated.

![Figure 2](image2.png)

**Figure 2.** Magnetization in ferromagnetic materials after being given an external magnetic field

One of the molecules that play a role in this case is the haemoglobin molecule. Haemoglobin molecule is considered to have an important role because it constitutes Fe atoms which are bonded with oxygen molecules (as in Figure 3). When haemoglobin molecules are in aligned position due to
an external magnetic field magnetization, this will facilitate the molecular oxygen to be separated from
the bond and oxidize damaged cells due to the same symmetrical position.

Figure 3. Haemoglobin structure in erythrocytes

Magnetic field can vibrate the ferromagnetic electric charge in the blood vessels, this vibration will
cause a movement of energy and heat. Motion and heat energy generated is useful to dilate the blood
vessels (vasodilation). Therefore, the blood flow that has previously been carried out by an electric
field, will become more fluent in the presence of a magnetic field.

Infrared wavelengths can penetrate into the skin tissue a few centimetres deep. In this process, the
water molecules in the network play a very important role, because the infrared light that is absorbed
by water molecules causes the water molecules to vibrate. This increases the vibration energy of the
water molecules. Because the energy increases, the temperature rises and the body that is exposed to
infrared light will feel warm. Other effects are the blood vessels become wider and the blood flows
more smoothly. Thermal effects caused by infrared light is used for therapy.

1.2. Diabetes Mellitus
Type 2 diabetes mellitus (DM 2), formerly referred to as non-insulin dependent diabetes (NIDDM) or
adult-onset diabetes, is 90-95% of the cases of DM. DM 2 patients experience insulin resistance and
relative insulin deficiency, therefore, at the beginning or even along the lives of patients with type 2
diabetes do not require additional insulin. In general, not all people with type 2 diabetes mellitus have
overweight or obese. Being overweight lead to various degrees of insulin resistance. Patients with type
2 diabetes who are not overweight or obese are likely to experience an increase in body fat percentage
mainly distributed in the abdominal [2].

The bond between insulin to the insulin receptor (IR) causes IR auto phosphorylation, which will
trigger various signalling pathways, including phosphorylation of tyrosine residues of insulin receptor
substrate (IRS). IRS 1 phosphorylation activates the signalling pathways for the translocation of
vesicles containing glucose transporter (GLUT 4) from the cytoplasm to the cell membrane and
activates anabolic pathway in muscle and fat cells (adipocytes), while the anabolic effect on the liver is
mediated by the phosphorylation of IRS 2. Translocation of GLUT 4 to the cell surface allows the
uptake of glucose by cells. Insulin-stimulated signalling pathways can be attenuated or tuned down by
various regulators. IRS auto phosphorylation can be restored to its original state by Tyr phosphatase-
1B (PTB1B). IR tyrosine kinase activity is inhibited by protein suppressor of cytokine signalling 1
(SOCS1) and SOCS2. Tyrosine phosphorylation and IRS activation is inactivated by serine
phosphorylation caused by the excess of nutrients or activation of stress pathways.

Insulin resistance is a condition failure signalling by insulin, which is commonly associated with
chronic over nutrition occurs in conditions of obesity (Muoiro & Newgard, 2008). Ann Louise (2012)
mentioned that insulin resistance is a condition where the cells are not able to respond to the normal
action of insulin. The result of insulin resistance is the uptake of glucose by cells that are sensitive to
insulin cannot occur. The fat cells (adipocytes) plays a role in insulin resistance because adipocytes
can produce adipokines (group of hormones and cytokines) and are capable of storing excess lipids in
obesity conditions. The excess amount of lipid can lead to a redistribution of lipid abnormalities to the
other organs and tissues. Adipokines produced by adipocytes, among others, are the leptin hormone,
adiponecint, retinol-binding protein and resistin, and proinflammatory cytokines such as interleukin.
(IL-6) and tumor necrosis factor-α (TNF α). Leptin and adiponectin are categorized as anti-diabetogenic, because it can decrease the synthesis of triglycerides (TG), stimulate β-oxidation of lipids and improve insulin action both in the skeletal muscle and liver. In obesity case, the leptin level is increased but adiponectin is decreased, indicating that in the obesity case, the resistance to leptin occurred (Muoio & Newgard, 2008).

Since the inception of obesity or high-fat diet (high-fat diets), metabolites derived from lipids (lipid-derived metabolites) accumulates outside adipocytes (including skeletal muscle, heart and liver). The accumulation in the liver resulted in the change of track long- chain acyl CoAs (LC-CoAs) to the endoplasmic reticulum and the cytosolic lipid such as diacylglycerol (dags), ceramide and triglycerides. This change is mainly governed by the presence of elevated levels of malonyl CoA induced by glucose. Malonyl CoA acts as both an intermediate precursor of de novo lipogenesis and carnitinepalmitoyltransferase allosteric inhibitor-1 (cpt1), which acts as a rate-limiting enzyme for carrying LC-CoAs into the mitochondria for β-oxidasi (Muoio & Newgard, 2008). Insulin resistance lowers the effect of insulin inhibition in peripheral lipolysis, increases the level of free fatty acids that can be taken up by the liver, and increases the risk of fatty liver (Krauss, 2004).

Lipids are transported from the liver in the form of very low density lipoprotein (VLDL), which is formed by the microsomal triglyceride transfer protein (MTP) that inserts triglycerides in apolipoprotein B (apo B). The decrease of the activity of MTP and the synthesis and secretion of apo B will reduce the liver ability to produce lipid and cause accumulation of triglycerides in the liver (Paschos & Paletas, 2009) (Figure 4). Prolonged insulin resistance will increase triglycerides, decrease level of high density lipoprotein (HDL) (Goyal et al. (2014) and increase small dense low-density lipoprotein (LDL), despite the plasma levels of LDL is normal (Bitzur et al., 2009).

Disruption or damage in liver function may increase levels of aspartate transaminase (AST / SGOT) and alanine transaminase (ALT / SGPT) (Oh & Hustead, 2011). Goyal et al. (2014) states that the increase of SGPT levels reached 20% of total patients with diabetes, especially in poorly controlled diabetes. Compared to AST, ALT which plays a role in gluconeogenesis is more correlated with the onset of lipid accumulation in the liver than AST.

**Figure 4.** Diagram showing the relation between insulin resistance and metabolic changes in liver

Chronic excessive nutrients induce dysfunction and pancreatic β cell death. Insulin resistance condition and pancreatic endocrine function declining are the causes of type 2 diabetes mellitus.

Increased blood glucose level is correlated with the increased blood viscosity, even though it is to a non-diabetic individual [3]. Tamariez et al. (2008) states that the increase of blood viscosity correlates with the onset of insulin resistance and type 2 diabetes are caused by problems with the arrival of insulin and glucose in tissues which is sensitive to insulin. Increased blood viscosity in patients with diabetes also affects the increasing workload of the heart in pumping blood to the vascular bed.
resulting in disruption in microcirculation, and the dense blood can damage blood vessels [3]. Disturbances in the microcirculation, according to Yagihashi et al. (2002) in Kostova et al [4] will result in the reduction of oxygen supplies and nutrients to the capillaries. This condition which was mentioned by Peduzzi et al. (1984) in Kostova et al [4] is a major cause of retinopathy in DM patients. Hyperlipidemic condition that often occurs in people with diabetes can also increase the blood viscosity [3].

Popel et al. (2005) in Kostova et al [4] mentions that regarding to the increasing of blood viscosity, erythrocyte (red blood cells) in DM patients are more prone to aggregate compared with non-diabetic individuals. The increase of erythrocyte aggregation was also observed in several pathological conditions. The increase of erythrocyte aggregation will also decrease the rate of blood flow and blood ability to carry oxygen to various peripheral tissues. (Foresto et al., 2000, [4])

2. Method
This study was conducted in two stages:

2.1. First stage
Instrument design that generates electric field, magnetic field, and infrared rays.

2.1.1. Design PSI equipment
The designed instrument is a combination of a permanent/constant magnetic field source of 100 mT (P), direct electric field (S) of 600V/m, and infrared (I) of 1 mW/cm², which would be presented to the group of experimental animals (mice). Each group of experimental animals are put in cages of a plastic tray (open top surface).

![Figure 5: Front-view PSI instrument, including infrared beam direction, constant magnetic field, and direct electric field](image)

2.1.2. PBI instrument design
This instrument is a combination of a permanent magnetic field source (P) 100 mT, an alternating electric field (B) with the frequency of 16 kHz, and infrared (I) of 1 mW/cm², which would be presented to the group of experimental animals (mice). Each group of experimental animals are put in cages of a plastic tray (open top surface). Front-view of Figure 8 of the treated animals sample box shows the direction of the light beam infrared, magnetic and electric field which was exposed to the experimental animals.
Figure 6: Front-view of PBI instrument, including infrared beam direction, constant magnetic field, and alternating electric field

2.2. Second stage.
To test the instrument from the first stage to know the combined effect of electric fields, magnetic and infrared rays to the mice with Diabetes mellitus

Animals/sample used in this research are healthy mice (mus musculus), male, 3-4 weeks old with a weight range of 25-35 g as many as 48 animals. Mice were induced into diabetic mice by the injection of streptozotocin (STZ). The procedure of mice induction based on the research by Novelli et al [6], in which the mice were induced by STZ dissolved in citrate buffer pH 4.5 at a dose of 20 mg/kg intraperitoneally in mice for 5 consecutive days (multiple low dose). On day 7 and 14 after the induction, blood glucose levels are evaluated in mice. Mice with glucose levels above 200 mg/dL will be classified as diabetic mice.

Subsequently the samples were divided into groups of healthy and groups of diabetic mice. Samples of diabetic group are divided into eight subgroups. Each group consisted of 4 mice. Each group treated with panel generating a permanent magnetic field, electric field, and the infrared except for the normal control group and diabetic control.

3. Result and discussion
The magnetic field affects the ferromagnetic substance- Erythrocyte aggregate conformation arrangement that cause the targeted cell membrane depolarization, decreasing the Blood viscosity so that Insulin resistance will decrease.

External electric field which is exposed to mice will lead to electronic polarization $\mathbf{P} = \varepsilon_0 \chi \mathbf{S}$, electronic polarization will cause an electric shift with vector density of $\mathbf{D} = \varepsilon_0 (1 + \gamma) \mathbf{E}$. Electric shift that occurred resulted in changes in refractive index of the cell that satisfies the equation $n_0(E) = n_0 - \frac{1}{2} n_0 \gamma_1 E$. The changes of refractive index that occur will increase the permeability of the cell plasma membrane, resulting in the increased flow of ions and water through plasma membrane. The flow of ions and water would lead to an increase in the conductivity of the plasma membrane that induce vasodilation then cause increasing blood flow and decreasing insulin resistance.

Infrared rays which is absorbed by water molecules cause the water molecules vibrate. Activation of the water at speeds increasing the ionization of water: $\text{H}^+$, $\text{OH}^-$ in microcirculation increase then produce heat that rise the body temperature, induce chemical reactions, affecting cell membrane permeability that increases Cytosolic free $\text{Ca}^{2+}$ then causes a rise of Insulin receptor activity and decreases of Insulin resistance.

The experimental results (Figure 7 to 10) proved that the treatment by combining the type of permanent magnet, the type of electric current (direct current and alternating), and the use of infrared light (with and without IR) to diabetic mice showed an improvement in fasting blood glucose levels.

These improvements demonstrated a significant reduction in blood sugar levels after 28 days of treatment in all combination groups (PSI +, psychotic, PBI +, PBI-) compared to diabetic control group (KD) and no significant difference with normal control group (KN). Tao and Huang [5] states that the provision of separate magnetic treatment can alter the aggregate red blood cells caused by hyperglycemia in diabetes condition into long chains. This change will reduce the viscosity of the blood and allows erythrocytes into the capillaries so the oxygen and nutrients transport to the tissues
becomes better. Electric currents resulting in vasodilation (widening of blood vessels) (Sullivan & Davison, 2001) and the use of infrared thermal effects make the treatment more effective. The decrease of blood viscosity, vasodilation and the effect of heat allows the reactivation of insulin signalling pathway, thereby signalling function returns to normal. Normally, the signalling function of insulin lowers blood sugar levels to normal blood sugar levels.

**Figure 7.** Profile of fasting blood glucose level to the treatments

**Figure 8.** Profile of weight to the treatments

**Figure 9.** Profile of ALT level to the treatments
4. Conclusion

From the results of this study, it can be concluded that:

1. For Diabetes Mellitus case, all combinations of permanent magnetic field, electric field, and the infrared rays (PSI+, PSI-, PBI+, and PBI-) can lower blood sugar levels, but the decline was contained in the optimum combination of PSI+

2. For Weight Loss case, all combinations of permanent magnetic field, direct electric field, and infrared light (PSI+, PSI-) and combination of a permanent magnetic field, alternating electric field, and infrared light (PBI+, and PBI-) can increase body weight.

3. For liver function (ALT and AST), the combination of PSI+ lowers ALT and AST significantly.

4. This study shows the potential of combination therapy instrument of permanent magnetic field, direct electric field, and infrared rays, which is effective and safe to improve blood glucose levels and hepatic function in diabetic mice.

References

[1] Saleh B E A, Teich MC 2007 *Fundamentals of Photonics* John Wiley & Sons Inc Hoboken New Jersey Canada

[2] American Diabetes Association 2011 *Diagnosis And Classification Of Diabetes Mellitus* Diabetes Care 34:S62-9

[3] Irace C, Carailo C, Scavelli F, de Franceschi MS, Esposito M, Gnasso A 2014 *Blood Viscosity in Subjects With Normoglycemia and Prediabetes* Diabetes Care 37 P 488-492.

[4] Kostova V, Antonova N, Velcheva I and Ivanov I 2012 *Comparative Analysis of The Rheological Properties of Blood Patients With Type 2 Diabetes* Series on Biomechanics 3-4 P80-85.

[5] Tao R and Huang K 2011 *Reducing blood viscosity with magnetic fields* Physical Review 00 001900 doi: 10.1103/PhysRevE.00.001900 http://ec.europa.eu/health/ph_risk/risk_en.htm accessed June 2016.

[6] Novelli MB, Bonamassa M, Masini M, Funel N, Canistro D, De Tata V, Martano M, Soleti A, Campani D, Paolini M and Masiello P 2010 *Persistent correction of Hyperglycemia in streptozotocin-Nicotinamide-Induced Diabetic Mice by A non-Conventional Radical Scavenger* Naunyn-Schmied Arch Pharmacol 382:127-137.