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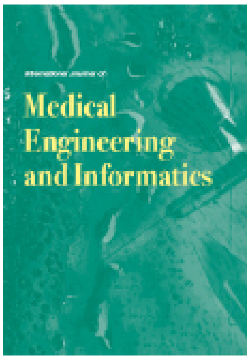

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Biothermodynamics may be a highly useful tool to help medical practitioners to detect and cure morbidities

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Biothermodynamics may be a highly useful tool to help medical practitioners to detect and cure morbidities

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Abstract: Biothermodynamics may help clinicians to diagnose and cure many medical cases, slow down ageing, correct malnutrition and repair the distorted tissues. Thermodynamically detected decrease in cardiac or renal filtration efficiencies indicate a malfunctioning system. Thermodynamic assessment of the circulatory system after amputation and restoring the circulatory pressure drop may prevent deaths. Research on thermodynamics of fertilisation may help to medical practitioners to fight against infertility. Athletes of some sports have substantially shorter lifespan than the other people. Biothermodynamics may offer some help to those athletes via prescribing appropriate energy intake. Distortion of the energy management in the body is observed in various health problems, including cancer. The need for multidisciplinary research to achieve additional understanding of these phenomena has been suggested by numerous researchers. Biothermodynamics may offer the best tool to achieve this goal.

Keywords: biothermodynamics; internal work performance; external work performance; energy and exergy efficiency; helping medical practitioners; diagnosing and curing morbidities.

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1 Introduction

1.1 Biothermodynamics aspects of the life processes

Assessing energy utilisation and entropy generation behaviour of the people may reveal the differences between the healthy and unhealthy individuals (Lucia et al., 2015; Çatak et al., 2018; Roll et al., 2019 Öngel et al., 2021). Thermodynamic properties need to be

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calculated at the physiological conditions to carry out such assessments (Çatak et al., 2018; Genç et al., 2013a, 2013b; Silva et al., 2021). Group contribution method (Joback and Reid, 1987) proved to be highly useful while determining the thermodynamic properties of the biological materials (Özilgen and Sorgüven, 2016). Organisms live by up taking energy or exergy and exporting entropy at far-from-equilibrium by maintaining constant internal physiological conditions via homeostasis (Yildiz et al., 2020b). A muscle cell may perform external work, such as walking, running, swimming and flying with the energy extracted from the nutrients to the fuel the conversion of ADP + Pi to ATP. Human walking may be simulated with the *inverted pendulum-like model of movement* (O'Neill and Schmitt, 2012), *the bouncing model* (Legramandi et al., 2013) describes locomotion of the body. Such models may be employed to improve the walking and running behaviour of the athletes and the handicapped people. Conversion ratio of the energy of ATP into muscle work is described as $\eta_{II} = \eta_{m1}\, \eta_{m2}$, where η_{m1} is the metabolic efficiency and η_{m2} is the muscle work efficiency (Çatak et al., 2018); η_{II} is also called the muscle contraction efficiency (Sorgüven and Özilgen, 2015) and estimates how much muscle work may be done with the chemical energy driven from the nutrients (Jubrias et al., 2008). Metabolic efficiency decreases if the mitochondrial membrane should get damaged and the mechanical work efficiency declines when ion pumps of the muscles deteriorate. Through evolution human body might have developed optimal control strategies for the muscle dynamics and the trajectories to achieve minimum energy utilisation (Alexander, 1997). Efficiency of the cardiac cycle varies along a day both in healthy and congestive health failure patients. Efficiency of the human respiratory system varies during resting, moderate and extreme activity levels (Dutta and Chattopadhyay, 2021). Obesity and insulin resistance and diseases are among the factors reducing the cardiac efficiency (Munoz-Diosdado et al., 2010). Any decrease in cardiac or renal efficiency indicates a malfunctioning system. Biothermodynamics studies focusing on these efficiencies may help medical practitioners to detect and solve such problems. A fraction of the entropy generated during the human body activities accumulates in the body and causes structural changes, as suggested by the *entropy theory of aging* (Hayflick 2007a, 2007b; Silva and Annamalai, 2008, Todhunter et al., 2018; Yildiz et al., 2020a). Kuddusi (2015), Patel and Rajput (2021) and Öngel et al. (2021) improved this concept. Öngel et al. (2021) based on estimates with four different diets confirmed that women had longer lifespan than men due to slower shortening of their telomers. Intermittent energy restriction may reverse diseases such as cardiovascular disease, diabetes, and neurodegenerative disorders in animals (Longo and Mattson, 2014).

Efficient ATP consumption is crucial for the sperm to reach the oocyte without exhausting its reserves (Tourmente et al., 2019). Energy allocation to the fetus and the mother for the life processes is a major issue during pregnancy (Semecioz et al., 2020; Rosello-Soberon et al., 2005). Varicioglu et al. (2019) calculated the exergy efficiency of the rat myometrium muscle contractions. Biothermodynamics studies focusing on increasing the exergy efficiency of these processes may help to ease infertility problem and help the women to deliver babies with less pain.

Nutrition is a major area for the biothermodynamics research (Buchholz and Schoeller, 2004; Semerciöz et al., 2018, 2020; Öngel et al., 2020). Exergy utilisation and destruction, daily work performance, muscle heat generation rates of the butter-fat-diet-fed lean rats were higher when compared to those of the soybean-oil-diet fed lean rats (Semerciöz et al., 2018). A fraction of the energy coming from the nutrients is lost with the feces and another fraction is stored in the adipose tissue, the remaining fractions may be allocated to reproduction, growth, synthesis of the building blocks and heat generation (Semerciöz et al., 2020). While performing these analyses Semerciöz et al. (2020) reported that the *internal work performance* was substantially higher than the *external work performance*. Internal work performance is a common concept for the biothermodynamics research, while it is rarely considered in other branches of thermodynamics. Entropy is generated during metabolic activity in living systems, most of it is exported, while a small fraction is accumulated (Yildiz et al., 2020a). Entropy accumulation in the body reveals itself as structural (Yildiz et al., 2020a) and DNA (Salminen and Kaarniranta, 2009; Lenart and Bienertova-Vasku, 2016) damages. Lee-Heidenreich et al., (2017) drew attention to the shortened life expectancy of the performers of some sports. Yildiz et al. (2021b), after employing the diet-based entropic assessment method, suggested a diet-based to improve the lifespan of the athletes.

Distortion of the energy management is observed in various health problems (Barclay, 2008; Garland, 2013). When an infection takes control of the metabolism, it causes scavenging of the healthy tissue to obtain energy and material to invade body (Thaker et al., 2019; Boroughs and DeBerardinis, 2015). In some diseases new blood vessels are generated in the diseased tissue to deliver the needed energy and the building blocks (Nishida et al., 2006). In lung cancer, disease-related entropy generation is 191 folds of that of the diet-related entropy generation and this is nine folds in skin cancer (Öngel et al., 2021). Garland (2013) draws attention to the need for multidisciplinary research to improve our understanding of cancer. Biothermodynamics may offer the best tool to achieve this goal.

Yildiz et al. (2021a) showed that a fraction of the metabolic entropy is generated by the gut microbiota and exported with feces without contributing to the ageing process of the host. Gut microbiota may be improved to enhance these benefits. The development of the gut microbiota agrees with the constructal law, which states that in order to continue to exist, being subject to constraints, a flow system must evolve in time to have easier access to its currents, as a result a global thermodynamic optimisation emerges (Bejan, 2002; Bejan and Lorente, 2011; Reis, 2016). Biothermodynamics research may be employed to predict potential positive mutations, which may then be implemented in the lab to the organisms.

1.2 How biothermodynamics may contribute to medical research

1 Protein unfolding and misfolding are common events in a cell cycle (Chaudhuri and Paul, 2006). Protein misfolding is among the primary causes of Alzheimer's, Parkinson's, Huntington's and Creutzfeldt-Jakob Gaucher's diseases and many other degenerative and neurodegenerative disorders (Chaudhuri and Paul, 2006). Biothermodynamics may help the medical practitioners to understand the cause of misfolding and may help to prevent it.

2 Humans store energy as fat and reuse it when needed. Assessments show that energy this process generates negligible ageing entropy. However, the migrant or hibernating animals, store with different purposes than that of humans, and its reuse generates most of their life span entropy (Ulu et al., 2021).

3 The rates of heart failure are high among people who have limb amputations (Modan et al., 1998), thermodynamic analyses offer an explanation to those deaths (Özilgen, 2017).

4 Yildiz and Özilgen (2021), argued that the aging related loss of functions in different section of the brain are possibly being caused by oxidation of the mitochondrial membrane and loss of the efficiency of the ion pumps in the brain tissue and suggested incorporation of the age-defying mechanisms of the muscles to the neuronal cells. In agreement with the constructal theory, Jeffery and Rovelli (2020) argued that if the brain can find new channels to enhance its entropy generation it may evolve; Herbert et al. (2020) after working on published experimental data concluded that the free locomotion patterns of the horses are developed via improving their designs over the years to minimise waste of energy.

5 Lenas (2018) while studying synthesis of bioartificial tissues commented that this process may be ensured after establishing appropriate thermodynamic conditions for development of the cellular patterns. Mukherjee et al. (2009) studied thermodynamic description of binding of a widely used class of molecules to human bone with the expectation of opening a way to the design of new drugs.

1.3 How to compromise

Researchers of biothermodynamics and clinical medicine must compromise at some point to benefit from collaboration. The following examples point the potential benefits of collaboration:

1 Following a myocardial infarction, the left ventricle undergoes a series of molecular, cellular, and functional alterations in association with the wound healing response. Gonzalez et al. (2016) described the wound healing process in a literature review, Iyer et al. (2015) referred to the laws of thermodynamics to interpret this process, analyses of Iyer et al. (2015) do not agree with the conventional reference to the laws of thermodynamics, a trustworthy collaboration may improve the benefits.

2 Hayflick (2007a, 2007b) made very important contribution to the establishment of the entropic age research. All the living beings die after generating a certain amount of lifespan entropy, since their bodies cannot stand accumulating more damage. Although Hayflick in his research referred frequently to 'entropy', he did not carry out any numerical studies. A trustworthy collaboration may put these benefits in numbers.

3 Silva and Annamalai (2008, 2009) and Annamalai and Silva (2012) made significant contribution to the entropic aging concept by quantifying entropy generation related ageing stress on individual organs. Their studies may be assessed with animal experiments to improve the benefits.

2 Concluding remarks

Human body responds optimally to heat, mass and energy flow in certain ranges, but its efficiency decreases drastically outside of these ranges. Human gut microbiata and many of the processes described in this study have evolved in time to have easier access to its currents as described by the constructral theory. Sarcopenia (Öngel et al., 2020) or inappropriate sports (Yildiz et al., 2021b) shortens lifespan due to wrong diets. Heart failure may come after amputation (Modan et al., 1998). There are a large number of neurodegenerative diseases resulting from protein misfolding and aggregation (Chaudhuri and Paul, 2006), biothermodynamics may help medical practitioners to understand and cure these morbidities.

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