Introduction

By

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Lieb has written an in-depth paper containing a wealth of information. This paper is comprised of three sections. The first section describes the physiological responses of the body during a hypothetical Watsu session. The second section begins with "Structure and Function of the Three Fluid Systems." This section is committed to a review of the anatomy and physiology of the circulatory, lymph and renal systems with an emphasis on the circulatory system. The final section begins with "The Action of Water and Shiatsu on the Circulation." It primarily restates the information from the first section of the paper and elaborates on some points with additional information.

For the practitioner not familiar with medical terminology, it may be necessary to keep a medical dictionary close by. The middle section, in particular, is crammed with detailed and technical information which, though interesting and informative, is primarily background information which illuminates our understanding of the circulatory, lymph and renal systems. Practitioners will find the first and last sections of the paper more useful.

When reading this paper, it is important to remember that very little Watsu-specific research has been done. Therefore, many of the statements made here regarding physiological responses to Watsu are assumptions and conclusions drawn from other areas of research. While there is strong evidence to support many of Lieb's points, some points are based on information which may just as easily lead to different conclusions. Additionally, some research in water immersion has led to conflicting results. While all of this is important to keep in mind, it does not detract from the value of Lieb's paper. It gives the reader an firm base from which to begin to understand the physiological responses to Watsu, and shines light on areas needing further research.

There are a few areas where Lieb's paper needs comment or clarification. For example, Lieb states that heart rate increases along with stroke volume during immersion. Although research studying heart rate during immersion shows some conflicting results, heart rate response to water temperature appears to be fairly consistent. At 25° C, heart rate does not increase, but instead drops by approximately 12-15 bpm . In thermoneutral water of 34° C, heart rate decreases less, but still drops[1,2]. It is only in very warm water that heart rate increases [3,4]. Cardiac output, on the other hand, always increases with immersion in water [5]. Increased cardiac output is secondary to the 700 ml increase in central blood volume which increases cardiac volume by 27-30%

with immersion to the neck [1,6]. The increased blood volume in the heart stretches the myocardium and thereby improves the actin-myosin filament relationship and results in a stronger contraction [3]. This causes an increase in end-diastolic volume, and a decrease in end-systolic volume. Stroke volume increases an average of 35% with immersion to the neck [6]. In other words, the heart pumps more efficiently by filling more completely and emptying more completely, and therefore pumps more blood with each contraction. Because more blood is pumped with each beat, the heart doesn't need to beat as frequently, and this is why heart rate drops in cool and thermoneutral temperatures. In thermoneutral temperature of 34-35° C, as is maintained in most Watsu pools, heart rate decreases and cardiac stroke volume increases. Although heart rate decreases, the net effect is still an increase of more than 30% in cardiac output [3]. (Cardiac output is the product of stroke volume times pulse rate per unit of time.)

Although Lieb recommends 34°-35° C water for Watsu, he sometimes casually interchanges the terms thermoneutral water and body temperature water as though they are the same. It's important to keep in mind the difference between the two. Thermoneutral temperature refers to water at a temperature which neither raises nor lowers core body temperature. Only 20% of the energy humans convert from food is used to do work. The remaining 80% is converted into thermal energy. If our bodies could not dissipate this heat, our core temperature would raise 3° C per hour during light activity. If our 37° C bodies are in 37° C water, we can't dissipate heat, and our core body temperature rises [7]. Therefore, body temperature water is not thermoneutral. 34°-35° C is thermoneutral for most people during a Watsu, but would not, for example, be thermoneutral for water aerobics. Also, the client's condition or the external environment may necessitate a different water temperature. A client with multiple sclerosis may respond better to a cooler water temperature [8]. A pool environment with very dry or very cool air temperatures may dictate a slightly higher water temperature.

Lieb also states that hydrostatic pressure is responsible for the 700ml increase in central blood volume. Other researchers conclude that buoyancy is at least an equal factor. They note that blood volume centralisation occurs regardless of the position of the body in water, even when upside down where the hydrostatic pressure gradient is reversed[9,10]. Interestingly, blood volume centralisation also occurs in astronauts in space where there is no pressure differential. This suggests that buoyancy, which reduces the effects of gravity, plays a key role in blood volume centralisation [11].

In describing the renal response to immersion, Lieb elaborates on how the antidiuretic hormone (ADH) is suppressed resulting in an increase in urine production. It's important to note that this response increases as the duration of

immersion increases up to three hours, and then it slowly begins to taper off [12]. This is of great significance for Watsu practitioners and all others who spend long hours in the aquatic environment. It is also important to note that atrial natriuretic peptide (ANP) is increased which contributes somewhat to diuresis by decreasing sodium reabsorption in the distal renal tubular system, but more importantly, increased ANP causes a suppression of thirst [13,14]. The increase in urine production coupled with the suppression of thirst can lead to significant dehydration, especially in clients who are medically at risk and practitioners who spend long periods of time in the water.

Lieb refers to the decrease in tension in the antigravity muscles secondary to the gravity counter-balancing effect of buoyancy. Although this is true, there is also a decrease in muscle tone throughout the body's muscles because of several additional factors. One of the most important of these factors is Watsu's influence on the Autonomic Nervous System (ANS). Watsu has a balancing effect on the (ANS) causing a quieting of the Sympathetic Nervous System (SNS) and an enhancement of the Parasympathetic Nervous System (PNS). [15,16] This leads to multiple benefits for clients, not the least of which is a dramatic decrease in muscle tone [17]. This decrease in muscle tone is of great significance to able-bodied clients suffering the effects of daily life stress as well as clients with special needs. Clients with orthopedic impairments experience a decrease in muscle spasm which provides pain relief. Clients with neurologic impairments experience a decrease in muscle tone which leads to a decrease in hypertonicity and spasticity.

Watsu's rhythmical, gentle rocking motions combined with repeated trunk rotation and trunk elongation further help to decrease muscle tone. [18] Virtually all areas of neurorehabilitation, including Neurodevelopmental Treatment (NDT and also known as Bobath) and Brunnstrom, recognize the value of trunk rotation in decreasing excessive muscle tone in the trunk, shoulders, hips and also the extremities. Proprioceptive Neuromuscular Facilitation (PNF) also incorporates rotation into all activities as the key element in facilitating normal patterns of movement.[19] Watsu utilizes both static rotational stretches for the trunk and rhythmical, repeated trunk rotation in many of its commonly used movements. These include the most basic Watsu movements of Rotating Accordion and both Near and Far Leg Rotation.

The vestibular system also has a powerful influence on muscle tone. Work done in Sensory Integration supports the muscle tone reducing benefits of the slow, rhythmical, repeated movements used throughout a Watsu session. [20] These movements gently stimulate the vestibular system causing a dampening effect on muscle tone. However, overstimulation of the vestibular system may have the opposite effect, and care must be taken during a Watsu session to monitor the system. [8,21]

Watsu's influence on the Autonomic Nervous System (ANS) may reach even farther in helping our clients. As more is learned about the adverse effects of ANS imbalance, many propose that ANS imbalance is the basis for numerous disease processes and impairments. These impairments range from fibromyalgia to reflex sympathetic dystrophy to post traumatic stress disorder and many more. (12,22) Clients experiencing ANS imbalance are often trapped in their fight/flight/freeze response which creates a physiological imbalance similar to pushing on the accelerator and the brake simultaneously. (23) Watsu has been used to help people move beyond the fight/flight/freeze response and onto a healthier life by helping to rebalance the

ANS. (1)

Through its wide range of effects, both physical and emotional, Watsu has far reaching benefits. It can help address many of our needs as humans, and improve our quality of life.

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Thesis

by

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Adaptive physiological processes of the human body during a one hour aquatic treatment, particularly in relation to the blood, heart, circulation and the lymphatic system*s*.

The Effect of Water and Watsu

During a Watsu treatment water acts upon the human body through the following agencies:

- hydrostatic pressure
- buoyancy
- temperature
- dissolved substances
- water resistance (viscosity)

These factors affect the body's functions synergistically (strengthening each other) or antagonistically (cancelling each other out). The program of client generated or passively received movements in the session and the amount of time spent in the water also have an effect on the body's adaptive reactions. In truth, seen from the outside, the body may appear to be coming into a peaceful state, but a powerful process of adaptation is set in motion, which not every constitution is able to undergo. From this fact arises a not inconsiderable list of counter-indications. The way in which the above mentioned factors affect the human body will be explained in the following hypothetical Watsu sequence.

After a pre-session interview and a shower, the client and therapist enter the treatment pool. They stand opposite each other, take hands and with every out breath allow themselves to sink up to their shoulders in the water. On inhaling they rise in a relaxed fashion slightly out of the water.

Within a short time, 700 milliliters of blood pumps from the legs and abdominal veins into the thoracic cavity and central circulation. Water pressure is responsible for this, compressing the veins just under the skin's surface, and aiding the venous valves in

shutting . Water pressure also compresses the abdomen and ribcage, so that with each inhalation, the veins there are more strongly squeezed, improving the transport of blood toward the heart. This occurs independently of water temperature and the activity or position of the immersed body. A healthy body is able to react to this increased quantity of blood through raising the cardiac output (liters per minute) by increasing the stroke volume and the heart rate.

Now the therapist brings his client into a horizontal position and slowly begins the Water Breath Dance, a gentle up and down movement in the rhythm of the client's breath.

The body's tissues are supplied with oxygen and nutrients through a combination of diffusion and filtration. Diffusion is movement of particles from an area of higher concentration to one of lower concentration. Filtration is transport of liquids through a filter or membrane which does not allow all particles to pass through; this is determined by the pressure gradient across the two sides of the filter and by the area of the filter's surface. The constant pressure of the water on the skin and on the underlying connective and muscle tissues obstructs the supply to these areas. In other words, the filtration out of the arterial capillaries into the tissue is reduced on account of water pressure.

At the same time, filtration or re-absorption into the veins is assisted (that is from the tissues into the circulation or the lymphatic system), because the pressure gradient is strengthened by the water pressure. The body's circulatory system is radically changed by water pressure. The fluid reserves in the tissue spaces between the cells in peripheral (superficial) areas are partially directed into the blood circulation. In the interstitial areas there are approximately 10 liters for supply of the tissues and as a reserve to compensate for a loss of blood. Because this liquid consists for the most part of blood plasma, the viscosity of the blood drops; the blood becomes thinner. To counter the under supply in the areas near the skin and to deal with the additional quantity of fluid, the body reacts in the following way: via the agency of the intracardiac self regulating mechanism (the Frank Starling Mechanism) the stroke volume of the heart rises. The augmented filling of the heart causes a stronger stretching of the heart's muscle fibers, and from this greater outward stretching a stronger capacity to contract results. The Bainbridge Reflex increases the stroke rate of the heart. This occurs through a reduction in the stimulation to the heart from the vagus nerve by blockage or increased pressure in the veins near to the heart and in the right atrium. The Frank Starling Mechanism and the Bainbridge Reflex taken together give rise to an increase of 30% in cardiac output. Simultaneously the muscle tone in the veins (the tension in the smooth muscle fibers in the walls of the veins) is reduced and makes possible the storage of much blood in the veins. (only 15% of the blood is normally found in the arterial system) The formation and secretion of noradrenalin weakens, causing a rise in peripheral circulation coupled with a decrease in peripheral resistance as the pre-capillary arterioles dilate. Pressure in the superficial capillaries is thereby raised and the arrested metabolic exchange in the skin, muscle and connective tissues is brought once more into operation.

In the meantime, we arrive with our client at the Accordion.

Through the rhythmic opening and closing of our client, not only is his breath stimulated, but the deep abdominal veins and the thoracic duct (the principle lymph vessel) empty heartwards with every folding together. With the next stretching open they fill again. The client's horizontal body position facilitates this fluid transport. The extension and flexion of the body and the joints brings the so called muscle and joint pumps into play. It is as if all the auxiliary engines aiding the heart simultaneously and with full force help the blood to stream through the body.

The body's third fluid system, the lymphatic system, is also more strongly flushed. The lymph system is responsible for the removal of macromolecular substances, disease causing elements and cancer cells. The lymph vessels, like the veins, are equipped with a valve structure. The vessels transport the lymph, first collecting it in close-ended lymph capillaries in the interstitial areas. The lymph is then conveyed toward the heart by the action of the contraction of muscles (the muscle pump) and the flexion of joints (the joint pump) and the rhythmic contraction of the lymph vessel musculature. The lymph is purified in the lymph nodes. In the event of pooling, the system is quickly overwhelmed, leading to an edema. In an edema, the lymph vessels are no longer able to pump the lymph toward the heart with contractions; the valves no longer close due to the vessel engorgement and dilation. When the body is submerged, however, the water pressure squeezes together the most superficial running lymph vessels and the valves can again close. This rise in pressure favors the reabsorption of edema located in the interstitial areas. The subtle water eddies on the skin occurring during a Watsu treatment also aid the heartward flow of lymph. All of this creates more lymph, but above all this fluid pours more rapidly into the circulation via the left subclavian vein, thereby augmenting the blood volume. An edema can harbour up to several liters of fluid that the body must subsequently process.

Therefore, in our pre-session interview we should first have clarified whether an edema has arisen through cardiac weakness with an associated venous blockage. Otherwise we would be creating yet another burden for a poorly functioning system. Likewise, when we work with cancer patients, we should be certain that no further lymph nodes are attacked, for the stimulation of lymph movement can bring about a spreading of cancer cells (metastasis).

In the meantime, with the Head Cradle, we have tractioned, twisted and mobilized the spinal column (especially the thoracic vertabrae), relaxed the intervertebral joints and with them the costovertebral joints.

The antigravity musculature (the back extensors) can fully relax in the absence of gravity.

Thus we arrive in Free Float. For the first time our client is able to take a few deep breaths on his own without our close presence.

Water pressure strengthens the exhalation, compresses the thorax and presses the diaphragm up into the ribcage. This compresses the lungs, decreasing their residual volume and expiratory reserve volume. There are more areas of the lungs aired (stale air expressed), but also the distribution of the inhaled air is more uniform, ventilating the apexes of the lungs, even. Water pressure makes breathing in more difficult. On the other hand, a maximally pre-stretched auxiliary respiratory musculature, the freely moving thoracic spine and ribs, and a diaphragm pushed high up, all facilitate breathing. It can be that the client even has the impression that he can breathe more freely, in the case of a breathing pattern with an inhibited exhalation, for example.

The gas exchange in the alveoli of oxygen and carbon dioxide is somewhat reduced due to the raised venous pressure. On account of the better distribution of air in the lungs though, the partial pressure of oxygen in the arteries, corresponding to the saturation of the blood with oxygen, increases in younger persons and remains unchanged in older individuals.

However, as the oxygen requirements of our client drop, he soon reaches a maximal saturation of oxygen in the blood. At the same time the carbon dioxide, diffusing 23 times more easily, is reduced. Thus, tetany, characterised by the hands curling into paws and cramping in the flexor muscles, as well as other signs of hyperventilation, can occur in a completely calm state with normal breathing.

This free respiration moves the entire ribcage and with it a multitude of large and small joints. An important pre-condition for the nourishment, regeneration and healing of a joint is its movement when unloaded or minimally loaded. From the thinning of the blood, the filtration to cartilaginous abrasions and of nutrients in general to the joints is promoted. A lower proportion of protein in the blood in contrast to a higher one in the synovial fluid makes this possible. Likewise, the intervertebral discs, which under load bearing lose a portion of their stored up liquid, benefit from this optimal supply situation as follows:

1) the anterior and posterior longitudinal ligaments are broadened by the stretches

2) the anti-gravity muscles relax

3) the blood supply is optimised

The engorged intervertebral discs are responsible, though not exclusively, for an approximately two centimeter lengthening of the spinal column after a one hour aquatic treatment. (Mitari, G.,Mano, T., Yamazaki, Y. 1981)

The nourishment of the nerves via their sheaths is often hindered by tense muscles. In this case better blood supply is brought about by the increase in circulation to the periphery of the body and the reduction in muscle tone. However, this can also lead to a passing increase in pain, as often a suppression of pain due to muscular tension has occurred. (Muscular tension reduces nerve conductivity.)

In the meantime, the general muscle tone is lowered through the effect of the nerves, through stretches or through massage.

A tensed musculature is always characterised by an under supply of oxygen and nutrients. The tension in the muscles hinders the blood transport into the tiny vessels within the muscles. It can even lead to splinting or complete contracture, for in order to relax, the muscle needs energy. This energy however, can neither be created nor led into the muscle. (Asdonk) The last energy to be generated in the muscle, ATP, leaves behind waste products, above all lactic acid, which cannot be removed. But the tensed muscles can bring about similar symptoms in cross or parallel running muscles. These areas encapsulate themselves, forming knots. These conditions can only be relieved through 1) stretching, in which the person's own kinetic energy is directed inward from outside the area; 2) massage, with kinetic energy supplied from another person; or 3) electrotherapy, an alternating current or ultrasound. When untreated, the presence of lactic acid in the musculature has been found to be directly associated with fear. (R. Wallace, H. Benson 1972).

In warm water and during a Watsu session the muscles of the limbs enjoy excellent conditions for blood transport. The blood vessels in the arms and legs and in the entire surface of the body are given preference, generously furnished with blood to counter the water pressure. The enrichment of the blood with oxygen is increased, and the blood is thinner, allowing it to flow more easily through smaller vessels. The heartward flow through the venous system is free and unhurried. The muscles are stretched from outside, and through the action of the nerves and hormones, are brought into a relaxed state. Lactic acid and other metabolic byproducts are carried away, and through elevated kidney activity, separated out from the blood. Not needing to supply energy for the generation of heat, the muscle cells enjoy a generous supply of oxygen and nutrients.

This could explain not only the pins and needles and alive sense that clients often report, but also for the tendency toward egotism and reckless behaviour in traffic and in private and professional situations. All this could be a consequence of the sharp drop in lactic acid and the thereby resulting loss of fear. Unfortunately, this hypothesis has not been scientifically investigated up until now. Clear, positive results have been documented in psychotherapy, without delving into the physiological changes. (C. Gütlin, H. Wallach. Frbg 1997)

In the meantime, our session slowly draws to its conclusion and our client demonstrates a slight tension in the pelvic region. Although the bladder had been emptied beforehand, it takes a while for the clear consequence to follow—it is full once more. Stretch receptors measure the state of fullness of both atria of the heart and of the great veins. They send their feedback about pressure and rise in volume to the fluid regulation center in the hypothalamus, which reduces the secretion of Antidiuretic Hormone (ADH also called Vasopressin--brings about contraction in the smooth muscle of the vessels in the posterior lobe of the pituitary gland). which in this way promotes the secretion of urine.

(Gauer-Henry Reflex).

It leads to a so-called Waterdiruresis in which the reabsorption of water in the distal tubules and in the collecting ducts of the kidneys is reduced. At the same time Atriopeptide is secreted from the muscle cells in the atria, which raises glomerular filtration, that is, more filtrate is created, the sodium reabsorption (together with water) is blocked in the collection ducts: This leads to diuresis and naturesis. Briefly summarized, the production of urine is increased, while the reabsorption of water and sodium is hormonally lowered. Thus, it can lead to the filling of the urinary bladder within an hour, and the need to empty it.

We now bring our Partner slowly into an upright posture once more, place him against the wall, release the physical contact and wait until he again assumes control over and responsibility for his own body. At this point we should offer several suggestions for the person leaving the pool to observe.

For clients plagued with chronic pain from damaged discs, briefly contracting all the muscles can to a certain degree counter the relaxation of the antigravity muscles and avoid the pain that quick movements and above all twisting the spine might provoke.

Normally, the spinal musculature hinders the pinching of a nerve or the damaging of a disc. Through relaxation, but also the overlaying of new physical experience, the body "unlearns" this use and the function of a specific degree of muscle tone. The client must, so to speak, make a "brake test" in order to consciously work with his musculature once again. At the same time, pressure increases on the blood vessels. When exiting the pool, the relaxed musculature in the walls of the vessels in the legs cannot withstand the pressure exerted on their now weighted fluid columns. A portion of the blood pools in the veins of the legs, resulting in less blood reaching the brain. Weakness, feelings of dizziness, and in extreme cases fainting may follow. Consciously contracting the muscles of the legs works against this happening, and the smooth muscles in the vessel walls will also be stimulated to contract.

Take a cold shower.

Drink a lot and possibly take some mineral salts.

Move slowly and drive slowly.

Structure and Function of the three fluid systems

Blood

The blood has the role of supplying every cell with combustibles from the food intake, along with oxygen, vitamins, hormones and heat. It carries away from the cells metabolic byproducts and heat. The blood consists of 45% blood cells (erythrocytes, leukocytes, and thrombocytes) and 55% blood plasma (91% water plus 9% solid parts-proteins such as fibrinogen) The blood volume totals 7-8% of the body’s weight (for a 70 kilogram person that would be 5 liters of blood).

Heart

The heart distributes the blood throughout the body. By contracting (systole) it pushes the blood through flap valves that point in the direction of the next chamber. The heart has two halves: the right or pulmonary half sends the oxygen-depleted blood to the lungs; the left or systemic half supplies the body with oxygen-enriched blood. Seventy milliliters are pumped into the aorta per contraction (stroke volume) and the approximately 70 times per minute heart rate or pulse, together determine the cardiac output. For an adult at rest, this amounts to 5- 6 liters per minute, but can rise to 20 liters per minute during strong physical activity.

Arteries

Blood is pumped out of the heart rapidly and under high pressure. The elasticity of the aorta compensates somewhat for the difference in pressure between the systole (pushing out phase) and the diastole (filling phase). In the increasingly narrower vessels of the circulatory system the pressure and speed of flow of the blood diminish, the arteries become arterioles and finally branch out to become capillaries. The arteries possess a relatively thick wall with much elastic connective tissue, interspersed with smooth muscle fibers. These fibers are controlled by the autonomic nervous system. When they contract, the arteries constrict, so that less blood can flow through. In this way small quantities of blood are managed and sent to the areas where they are needed in the moment. For example, after a meal the blood is directed to the digestive tract. The capillaries often form three dimensional networks, fed from several arterioles with cross connections (collateral arterioles). In these smallest of vessels found throughout the tissues, the metabolic exchange with the cells takes place. The volume of blood that flows through is controlled by the pre-capillary sphincters. The vessels are so narrow (0.004 – 0.015 mm.) that the blood cells are forced to change their shape to be able to pass though. The speed of the flow, which in the aorta still amounted to 20 cubic centiliters per second, sinks to 0.05 centiliters per second. The capillary walls are thin, the surface available for exchange is large (40 billion capillaries with 600 square meters surface). The exchange takes place via three processes:

a) Diffusion

b) Filtration

c) Pinocytosis.

Diffusion is the movement of particles from a place of higher concentration to one of lower concentration. Water soluble molecules (sodium chloride, potassium chloride, glucose) diffuse through the pores, and fat soluble materials (oxygen and carbon dioxide, nitrogen, alcohol) diffuse through the entire endothilial surface.

Filtration is the transport of fluid through a filter or membrane that does not allow all the particles composing the liquid to pass across. The amount that filters across is dependent on the difference in pressure between the two sides of the filter and on the surface area

of the filter. Filtration is critical for the rapid exchange of fluid between blood plasma and the interstitial space. In the arterial segment of the capillary, fluid filters out, which in the venous segment is up to 90% reabsorbed. This happens as follows: The capillary walls are hardly permeable to proteins (macromolecules). They keep the fluid in the capillaries by virtue of the oncotic suction (or colloid osmotic pressure, the pressure exerted by the plasma proteins). If, however, the blood pressure in the capillaries, that is the hydrostatic pressure (Pcap) is higher than the collolid osmotic pressure (Pcoll) of the plasma proteins, then fluid will be filtered out of the capillaries. However, the tissue also has a hydrostatic pressure (Ptis) and through its protein parts in the interstitial fluid a colloid osmotic pressure (ptis), so that the operative filtration pressure is expressed as Peffect = (Pcap – pcoll) – (Ptis – ptis).

Filtration is not a flowing through, rather an exchange with the fluid stored in the interstitial area. This stored fluid serves the blood circulation as a plasma reserve in case of a sudden loss of blood, as from a wound or from blood donating. Therefore, three days before and after a Watsu no blood donating. The filtration volume totals 20 liters per day (Bartels), (Földi speaks of 70,000 liters per day), from which only 18 liters are reabsorbed by the venous system. The difference is drained off via the lymph system and then shortly before reaching the heart, again directed into the circulation via the superior vena cava.

A disturbance of this mechanism leads to a pathological accumulation of fluid in the interstitial spaces or in the cells of the tissues, an edema. The causes of edema are:

1. elevated hydrostatic pressure, for example with heart failure; venous thrombosis, in which there occurs a damming of the venous blood (counter-indication for Watsu).
2. Lowered oncotic pressure, for example with kidney disease with protein loss
3. Damage to the capillary walls associated with burns, poisoning or allergic reaction
4. Disturbances in the lymphatic return following an operation, or on account of tumors, parasites, valve failure, lack of movement or constrictive clothing

In the process of pinocytosis, large molecules are encapsulated and transported through the cell walls, then again released into the interior. This occurs principally with proteins in the areas close to the venous capillaries. The return flow to the heart takes place via two systems. Firstly, the venous system, fed directly from the capillaries, returns to the heart the carbon dioxide rich blood along with the reabsorbed smaller-moleculed substances. Secondly, the lymph system conveys the remaining filtration volume heartwards, principally the macromolecule proteins.

Veins

Veins have significantly thinner walls than arteries, but the same structure otherwise.

The transport of blood via the venules, veins and the great veins happens through four mechanisms:

1. The majority of veins contain valves functioning as flaps, that is, they direct the flow of blood heartwards and impede any back flow occasioned by gravity. The pressure on any single valve corresponds only to that of the column of fluid up to the next valve.

2. Muscular contraction and joint movement convey the contents of a given section of vein heartwards. A steady pumping action is exerted by the arterial pulse on neighboring veins.

3. Breathing increases the negative pressure in the thoracic cavity. The veins lying in this area fill up through the sinking of the diaphragm. The resultant rise in pressure in the abdomen favors the flowing of blood into the thoracic cavity.

4. The contraction of the heart's ventricles exerts a suction on the atria, which contributes especially to the filling of the right atrium with venous blood.

The ability of the venous system to store blood can be enhanced by 75% through the elasticity of the vessel walls. In the horizontal position or immersed in water this storage capacity drops, especially in the legs, as there is no vertical column of blood to counter the emptying action of the veins. Water pressure compresses the superficial veins. When standing up quickly or in climbing out of the water more than half a liter of blood pools. This lowers the cardiac output, the arterial system is not sufficiently supplied, and can occasion a temporary shortage of blood to the brain and possibly fainting. Through client generated movement (lying down or immersed in water), standing up or sitting up slowly, leaving the pool slowly, and pouring cold water on the legs, this absence of blood is counteracted. Chronic pooling in the veins of the legs through long periods of standing, pregnancy, or sitting activities with pinching of the large abdominal veins can lead to vericose veins with the danger of inflammation and the formation of thromboses.

Lymph vessels

The transport of the remaining portion of fluid, about 10%, happens via the lymph vessels. The liquid arrives passively in the lymph capillaries, which come to blind endings in the interstitial spaces. Macromolecules such as protein, immobile cells, waste matter, bacteria, viruses and large fat molecules are reabsorbed by the lymph system, just as, for example, the plasma proteins enter into the interstitial fluid from the venous portion of the capillaries. Lymph has, however, a lower protein content than blood: 2% in contrast to 7.4% in the blood. The further transport of the lymph is achieved by the rhythmic contraction of smooth muscle in the lymph vessel walls, where the valve structure prohibits pooling. Gentle, external pressure upon the interstitial areas and the peripheral lymph vessels (water pressure, compression bandages or manual lymph drainage) raise the body's own lymph drainage volume. (Földi). Likewise, this is supported by deep breathing, the movement of the skeletal musculature and peristalsis in

the large intestine. After purification in the lymph nodes, the lymph fluid arrives once again in the venous system.

Lung circulation

From the right side of the heart, 98% of the blood pumps into the lungs, gives up its carbon dioxide in the lung capillaries and then leaves the lungs through the pulmonary veins, enriched with oxygen. Oxygen binds with hemoglobin to form oxyhemoglobin, the red component of erythrocytes, which release oxygen in the capillaries. This then dissolves into the tissues. Carbon dioxide, on the other hand, is carried along as a gas, dissolved in the watery portion of the blood, where part of it reacts with water to form carbonic acid (H_2CO_3). The vessels of the lungs posses great elasticity, as they are surrounded only by a thin connective tissue layer and the airy alveoli. The pulmonary vessels are therefore equipped to store an additional quantity of blood that is made available to the heart at the outset of physical activity.

Regulation of the circulation

If all blood vessels were to be simultaneously filled, 20 liters of blood would be required. As only 5 – 6 liters are available, it must be distributed according to need. For example, as requirements for oxygen in the muscles increases, the heart rate and stroke volume (cardiac output) rise and the arterioles, connected by capillaries, dilate. This control can happen locally or centrally (from the cardiovascular center).

1. **local regulation**

   a. Automatic Self Regulation. In order to guarantee a constant pressure, the arterioles may either constrict or slacken in reaction to pressure, in the latter case letting the vessel muscle fibers go limp.

   b. Local Chemical Reactions. A vasodilation results, for example, by a rise in the local CO_2 partial pressure, drop in the ph value, lowering of the O_2 partial pressure, by a rising of the concentration of adenosindiphosphat (ADP), Adenosinmonophosphat (ADM), Adenosin and Postassium in the skeletal muscles, and above all with a strengthened rise in CO_2 and lactic acid. Local chemistry also works through kinine, (vasodilation), histamine (vasodilation), serotonin (vasoconstriction), and angiotensin II (after the release of renin from the kidneys, a substance formed in the blood plasma generating vasoconstriction, is involved in the blood pressure regulation and in water and electrolyte regulation).

1. **central regulation**

Central regulation is mediated by the cardiovascular center, that controls from its location near the respiratory center in the medulla. It can act to create vasoconstriction with a raising of sympathetic tonus and activation of the heart's activity. Or it brings about vasodilation with a checking of the sympathetic tonus and diminishing of the heart's action in the transport of blood.

The vasomotor center is constantly active and maintains a resting tonus in the vessel musculature. The different centers receive their information from the higher brain centers (in the cortex and hypothalamus). They also receive information from the pressure receptors in the carotid sinus and the aortic arch and the chemoreceptors of the glomera (carotid, aortic). From the breath center, comes feedback about the gas and composition of the blood. The excitation of pain receptors also work upon the cardiovascular center. The secretion of adrenalin, a hormone from the adrenals, is 15% responsible for vessel narrowing, Renin formed in the kidneys turns angiotensinogen into angiotensin I, that primarily in the lungs, is enzymatically activated to Angiotensin II. This is one of the strongest vasoconstricting substances. Failure of the cardiovascular center means that the organs such as the brain and kidneys receive too little blood. This can ensue after blood loss, and from orthostatic or heat shock.

Water, salt maintenance and kidney

Equilibrium is achieved by intake and excretion of fluid. As in the cells, so in the entire body. Responsible for the elimination of water are not only transpiration in the lungs and skin(0,9 l), and fluid loss in the stool (0,1 l), but the kidneys as well. They serve the homeostatis of water, of electrolytes and of osmotic pressure of the bodily fluids. The regulation is controlled by the osmotic receptors in the hypothalamus.

The functional unit in the kidneys is the nephron (l – 1.5 microns). It consists of a knot of capillaries (glomerulus) and a capsule to lead away the filtrate (Bowman capsule) through which daily 170 liters of filtrate passes, and the tubules in which 99% of it is recycled. This reabsorption happens through a colloidal osmotic pressure differential, moreover electrolytes become active, promoted through a counter flow system which reclaims the filtrate. The remaining urine (1.5 liters) is stored in the bladder and eliminated in quantities of .4 liters.

The Action of Water and Shiatsu on the Circulation

The constant pressure of water on the skin and the underlying connective tissues reduces the transmural pressure and strengthens the reabsorption in the capillaries. Thus the filtration volume is reduced while at the same time the return flow of fluid into the venous portion of the capillaries is raised. The storage capacity of the venous system in the legs and in the abdominal region is reduced on account of the horizontal posture (the falling away of the columns of blood) and the water pressure on the superficial veins. Inadequately working veins (too dilated) are emptied, as the veins are pressed together by water pressure and the valves again close. By virtue of the folding and opening movements (for example, the Accordion) the muscle and joint pumps are brought into play. Through the pressing together of the abdomen in combination with the deepened breath, nearly all the auxiliary motors of the venous transport are activated. As relates to the lymph, re-absorption is likewise strengthened due to water pressure and the massaging action of the water resistance and the pressure on the interstitial spaces. The subcutaneous running lymph vessels experience a strengthening of their valve pumping

action from the water pressure. Also here, the disappearance of gravity in connection with the muscle pump, breath and abdominal movement leads to a quicker fluid transport to the heart. Already on entering the pool on average 700 milliliters in the low pressure system (lymph and veins) are transferred from the arm and leg veins toward the thorax. The central blood volume thereby increases, the central venous blood pressure rises, likewise the blood pressure in the lungs; the storage capacity of the lungs is strongly utilized. The blood composition alters, as more interstitial fluid enters the circulation, the red blood count and viscosity sink, the plasma volume climbs and the blood becomes thinner.

The following factors work synergistically or antagonistically through the warmth of the water

The warmth of the water creates a widening of the vessels (vasodilation), especially a lowering of the venous tonus, an increase in diffusion and stimulation of cellular metabolism, a sinking of the arterial blood pressure and a rise of cardiac output. As the warming action is negligible in lukewarm, body temperature water, it is the movements of Watsu that create warmth. Additionally, the relaxation of the musculature is an energy consuming process, so the effect of warmth in contrast to that created by movement and water pressure is negligible. Should the water temperature fall below 34° C., this leads, proportionate to the drop in temperature, to constriction of the blood vessels and a climb in blood pressure, stimulation of the metabolism to generate warmth, and activation of the sympathetic nervous system. It wakes us up.

On account of the transfer of blood into the central circulation, there arises an increase in the stroke volume and heart rate, mediated by the intracardial self regulating mechanism (Frank Starling mechanism) together with the Bainbridge reflex (lowering of the vagus tonus and thereby an increase in heart rate on account of filling up or rise in pressure in the veins near the heart). In total, the cardiac output climbs 30%.

The baroreceptors located at the point of division of the carotid artery (the carotid sinus) and in the wall of the aortal arch signal the pressure increase to the cardiovascular center, which induces the increase in heart rate. The stretch receptors, which measure the state of fullness of both atria and the greater veins, direct their feedback to the fluid regulation center in the hypothalamus, which reduces the secretion in the posterior lobe of the pituitary of antidiuretic hormone (ADH—identical with vasopressin—creates contracture in the vessel smooth musculature). The elimination of urine is in this way promoted (Gauer-Henry Reflex). It leads to a so called water diuresis in which the reabsorption of water in the distal tubules and in the collection ducts of the kidneys is reduced. Simultaneously atriopeptide, which raises glomerular filtration, is poured out of the muscle cells in the atria. That is, more filtrate is created, reabsorption of sodium in the collection ducts is lowered (together with that of water). This leads to diuresis and natriuresis. The formation and secretion of noradrenalin is weakened, which favors the increase of the peripheral circulation with decrease in the peripheral resistance. The

peripheral precapillary arterioles dilate, the pressure in the capillaries increases in order to counter the pressure from outside and to guarantee the filtration in the skin and connective tissues. The formation of renin is checked, and the circulating renin-angiotensin-aldosterone system is also checked. (Angiotaensin II. affects the release of aldosterone from the suprarenal cortex, which furthers the Na+ reabsorption, raises simultaneously the rate of secretion for K+ and H+ ions.

Physical effects of water and the human body's response

The stimulating and simultaneously calming action of water has been recognized since antiquity. Most recently in the roman bathing culture, this understanding spread across Europe. When used externally, water works equally upon the psyche and physiology; taken internally it is nourishment. Drinking water ensures homeostasis (self regulation of the body to maintain healthy equilibriums) and homeothermy (regulation of body temperature). Water dilutes or washes out of the body harmful and toxic substances. Water cleanses internally as well as externally. Used externally, by remaining for some time in a therapy pool or by receiving a Watsu treatment, water acts via the following factors:

- hydrostatic pressure of water
- buoyancy, temperature, the substances dissolved in the water

These factors influence synergistically or antagonistically the body's functions. Additionally, the effect of movements administered in water is completely different from the effects of movements or massage out of water.

Heat

Water transmits heat 250 times better than air. For this reason water is utilized in heat therapy. The changes in temperature influence all the body's reactions, particularly circulation, endocrine, vegetative and neuroendocrine. The influx or withdrawal of heat stimulates the heat receptors in the skin and excites the central regulatory mechanism to maintain the equilibrium of the body's core temperature, seldom to raise the core temperature. Because Watsu is practiced in a thermally neutral environment (isothermie of 34.5° +/- 0.5° C), the action of temperature may be ignored. Certainly, a slight muscle activity happens through the movement and massage of the muscles, so that a slight overheating can result

Stretching, massage, every kind of muscular relaxation is an energy burning and heat producing process. This overheating strengthens the capillary diffusion (the distribution into the smallest blood vessels), dilates the vessels in the skin, sinks the arterial blood pressure which becomes however shortly afterwards increased, as blood flows into the central circulation as the venous and lyphatic blood volume raises. The stimulation to the sympathetic nervous system increases the heart rate and cardiac output. Warming relaxes the muscles, renders the connective tissue stretchable and the bodily fluids thinner, including the synovial fluid in the joints. This leads indirectly to an improved

nourishment of the cartilages and the breaking down of cartilagenous abrasions in inflammed joints. Heat effects psychic complaints and stimulates the immune response, supported by movement and massage. with chronic inflammation it works antiinflammatorally and analgesically (pain reducing). Warming raises blood viscosity due to dying off of erythrocytes; thicker blood leads to clumping and hinders the blood transport.

The effects of warmth

increase in diffusion

vasodilation

sinking of arterial blood pressure

raise in the heart rate and cardiac output

lowering of tone in the veins

activation of cellular metabolism

reduction of viscosity in bodily fluids

loss of tone in skeletal muscles

emotional relaxation and detonifying

analgesia

antiphlogistische effect

immune modulation

stimulation of mild hyperthermia

suppresion of marked hyperthermia

vegetative hormonal adaptation and habituation (long term effect)

Antigravitation

According to the Archimedes principle, a body immersed in liquid loses in weight exactly as much as the fluid it displaces weighs. According to Strassburger, a man weighing 70 kilograms will weigh only 2.5 kilograms in water plus the weight of the parts of the body that are out of the water. In concentrated mineral or saltwater baths, buoyancy is stronger; the body appears to be weightless. This reduction of gravity effects the skeleton and the muscles, as well as the nerve supply. The antigravity muscles relax in water, reflexive contractions are not necessary. The spinal column lengthens about two centimeters during an hour long session (via the taking on of fluid and enlargement of the discs).

Any pressure on the nerve roots where they exit is reduced; and thereby also organic or motor disturbances, and sensitive aliments can be relieved or ameliorated. (breaking the "devil’s cycle" of pain). From the reduction in tension in the antigravity muscles and the

stimulation of a strengthened out breath (passive) and in breath (against the resistance of the water/hydrostatic pressure), there arises a massaging action of the breath on the thoracic spine, on the ribs (specifically the costovertebral joints), on the scapula and clavicle, even on the lumbar spine from the strengthened diaphragmatic movement. The thoracic spine becomes freer, its original function of rotation can more easily take place, the flexibility of individual vertebral joints or costovertebral joints can be tested, mobilized and supported. The flexibility of the muscles increases as the oxygen requirements sink and metabolism drops. This works together with the stretches, twists and movements of Watsu. A mobility in the vertebrae can be achieved which is seldom attainable in land treatments., but the danger of an instability in a hypermobile lumbar or cervical intervertebral joint is present, for even the protective tonus of the muscles falls away.

Therefore, contracting all the muscles before leaving the pool is recommended, and abrupt twisting movements of the back are to be avoided.

Hydrostasis

Hydrostatic pressure brings about a centripetal apportionment of the blood with an increase in the central blood volume and a transfer of interstitial fluid into the circulation. This means that in a person standing neck deep in water, lying supine the water, water pressure squeezes the superficial veins and lymph vessels. This is a similar effect as when a compression bandage relieves edema. Even dilated sections of lymph vessels or veins with inadequate valve pumping action empty out, to the extent that there is no resistance to the flow through into the central circulation (blockage in the vena cava or thoracic duct) Between 0.7 – 1.01 liters of blood will be transferred intrathoracically and this out of a total volume of 4 – 7 liters. This transfer of liquid is further strengthened in Watsu or with hydrotherapy by the muscle and joint pumping action. Specifically, in Watsu the transport mechanism in the vena cava and thoracic duct is aided. The relaxation of the vessel musculature, the same as the widening of the superficial veins and lymph vessels, by the simultaneously facilitated flow out, allows a withdrawal of intersitial fluid, which is directed into the central circulation. Thereby the stroke volume of the heart climbs around 30% with a simultaneous minimal increase in the heart rate. The hemocrit (total of red blood cells) and blood viscosity sink, the plasma stored in the interstitial spaces thins the blood, the rate of flow increases. The peripheral resistance sinks, the peripheral circulation picks up. The kidneys intensify the secretion of urine and sodium, caused by an increase of the flow through the kidneys and the slight climb in arterial blood pressure. (Hartmann).

Raising of the Atriopeptide level-

- Curtailment of Vasopressin (adiuretrin, Henry Lauer Reflex) (a ind er neurohyphophyse created hormone, favors the concentration of urine, released via the osmotic receptors)
- increase of renin activity (originating in the kidney), forms angiotensin III, the

strongest vasoconstrive substance, raises the peripheral resistance)

- reduction of aldosterone (mineralcorticoid from the adrenal cortex, reduces Na+ and increases K+ and H+)
- reduction of noradrenalin (hormone, neurotransmitter, blood pressure raising)
- strengthening of the renal prostaglandin E^2 secretion (lowers the A. t. tonus, raises the blood supply to the kidney and the formation of renin)

Breath

In the breathing out phase of the breath cycle, the diaphragm rises toward the head and transmits pressure into the thoracic cavity. This action reduces the lung volume, strengthens the exhalation, the tidal volume rises, the expiratory reserve diminishes, the distribution of air into the apex of the lungs improves. The arterial partial pressure remains the same. The alveolar gas exchange is minimally reduced, the arterial oxygen pressure increases with younger patients and remains the same with older patients. The muscles involved with inhalation are effected by the water in the sense that they are strengthened by the resistance after several treatments, leading to a better development of the breath and flexibility through the thorax. The simultaneous relaxation of the antigravity muscles occurs through the reduction of gravity as a consequence of the buoyant force. From this the deepened breath has a massaging effect on the entire ribcage, especially the thoracic spine.

Mineral Baths

Very little of the minerals and elements dissolved in water are absorbed through the skin. Rather, they are temporarily deposited in the skin or act upon the nerve receptors in the skin. They may also gain entrance into the body through the respiratory tract.

Viscosity (internal friction of a fluid)

In Watsu, viscosity plays a supportive role, creating a buoyancy for the body moved in water. The body in water swims though the subtle turbulences occasioned by the movements. The skin, the subcutaneous connective tissue and fat, and the superficial musculature are all massaged by this action. This promotes circulation and enhances the performance of the muscles. In a series of sessions, adipose tissues break down and reform as cushioning in other areas. The body becomes rounder; a comparable phenomenon occurs in swimmers.

Suggestions for the client after leaving the pool

The client with spinal instability should tense all the muscles of the body before leaving the pool. This will render the postural musculature once more ready for action. Quick bending or turning movements should be avoided. Due to the stretching out of the smooth musculature in the veins, their valve pumping mechanism, especially in the legs, can be compromised. This leads to a sudden loss of blood pressure, and consequently insufficient circulation to the brain, occasioning dizziness, loss of concentration or even

fainting. Therefore it is recommended to leave the pool slowly and drink lots of fluid (no alcohol), if need be, with mineral salts; for above all sodium has been lost. It is especially important, however, to at least give the legs a cold shower, in order to contract the muscles in the vessels of the legs. Even if the vessels again relax open after warming, by repeating the cycle (the so called "vessel jogging") the muscles of the vessels are trained to adapt and perform. A 15 minute rest with the legs elevated is likewise recommended. After a session, patients with instability of the vessels should put on support stockings, support hose, and then support bandages.

Conclusion

Bathing in warm water is a stimulus whose effects have been researched since Roman times and subsequently verified in controlled studies. Vascular instability, cardiac problems, open wounds, inflammations or infectious diseases rule out treatment in the therapy pool. With Watsu, various psychic disturbances enter into the picture as additional counter-indications. Contrary to general opinion, the power of water is in no way passive; rather it is an active stimulus, able to be utilised in a directed fashion for the strengthening of normally functioning physical systems and for the improvement of those which are disturbed. When the client participates actively in a program of movement, the length of a water treatment must be abbreviated, the higher the temperature of the water. In this case the time and possibility for the body to adequately react to changes and to take advantage of the benefits of water are reduced. These benefits would include joint mobilisation without weight bearing with relaxed muscles and improved circulation. This shortened time in the water can be extended when the client remains passive, allowing manipulation and mobilisation without active participation. The demands upon the circulation and the risk of overheating are then reduced. Watsu or a program of passive movement administered to the client offer an ideal opportunity to support and empower the healing action of water in all areas.

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