# Water immersion model in nephrology: from hydrotherapy to weightlessness

**Jan Dulawa, Michal Kokot**

Department of Internal Medicine and Metabolic Diseases
SHS, Medical University of Silesia, Katowice

***Corresponding Author***: Professor Jan Dulawa
Department of Internal Medicine and Metabolic Diseases GCM ul. Ziolowa 45/47, 40-635 Katowice
e-mail: jdulawa@sum.edu.pl

**ABSTRACT**
The term immersion connotes a wide range of different procedures ranging from whole body immersion to head-out water immersion carried out utilizing diverse body postures and water temperatures.

Though hydrotherapy has been used for centuries, it was the space program in the sixties of the twentieth century, which gave a new impetus to this procedure as an nonaggressive investigative tool, which has been used in studding the influence of weightlessness on hemodynamic, metabolic, hormonal and nervous system. It was possible because water immersion mimics the weightless state on earth.

During the next years head-out immersion model was used by scientists to investigate function and pathophysiology of cardiovascular system, liver and kidneys. After recognition that water immersion induces diuresis and natriuresis, the procedure has been used to study and to treat the disorders characterized by impaired volume homeostasis, as decompensated liver disease, nephrotic syndrome, essential hypertension, cardiac transplantation, diabetes, primary aldosteronism and pheochromocytoma.

Between investigative groups, which contributed the most in studies with using head-out water immersion model there are teams of M. Epstein (Miami, USA), J.E. Greenleaf (USA), P. Norsk (Denmark), A. Koomans (Utrecht, The Netherlands) and F. Kokot (Katowice, Poland).

**KEYWORDS:** water immersion, nephrology, hydrotherapy

## Introduction

Hydrotherapy is probably as old as mankind. It is one of the basic methods of treatment widely used in natural medicine, and has also been referred to as water therapy, aquatic therapy, pool therapy and balneotherapy.

Hydrotherapy dates back as far as ancient Egyptian, Greek and Roman times, when Egyptian royalty bathed in oils and Roman bath were frequently visited by its citizens. There is also historical evidence of such therapies having been used in the Far East, e.g. China and Japan – where hot springs were frequently used by people to bathe in. However, in those times people used hydrotherapy exclusively for relaxing and indulging themselves and it was only in the 19th century, that hydrotherapy started to resemble the therapy that it has become in today's society. Heinrich Friedrich Francke (1766-1838), Vincent Priessnitz (1799-1851) and Sebastian Kneipp are supposed to be the pioneers of hydrotherapy.

## Water immersion as a type of hydrotherapy

Nowadays hydrotherapy procedures can be divided to:

1. Surface hydrotherapy with absorbent materials (e.g. washes, friction rubs, wraps packs and compresses);
2. Hydrotherapy showers with variations in water striking pressure (douches, showers);
3. Procedures based on the effects of hydrostatic pressures (under massage, whirlpool bath, exercise in water, full and partial immersion bath).

Among partial immersion modalities, head-out water immersion is of particular importance. Its effect on different body organs depends on water temperature. Therefore immersion in water at temperature e.g. 14, 20 and > $36^0$C is commonly referred to as thermotherapy.

In the next part of the paper the head-out water immersion in neutral bath, ie. at temperature approximately 32-$36^0$C will be discussed and referred to as WI.

## Differences between WI and saline administration

The most important effects of WI in humans are (1):

- prompt redistribution of circulating blood from the periphery to the heart and great vessels of the chest and the neck, especially in the areas with volume-, baro- and chemo- receptors with a relative central hypervolemia,
- increase in cardiac output by 25-33% and central blood volume by ~ 700 ml,
- progressive diuresis and natriuresis equally in magnitude to those induced by acute NaCl administration (2 l/2 h).

Despite of many similarities, there are some significant differences between WI and saline administration (1).

1. WI is associated with decrease in body weight rather than the increase that occurs after saline infusion.
2. Majority of studies have indicated that systematic blood pressure is unaltered during immersion in normotensive studies and can decrease in patients with hypertension. Saline infusion always causes increase in blood pressure.
3. WI doesn't cause any changes in plasma compositions, while saline infusion does.
4. WI entails a central hypervolemia without concomitant peripheral hypervolemia, whereas saline administration involves both a central and peripheral hypervolemia (in majority of studies).
5. And, what is also important, action of WI is promptly reversible, while saline infusion doesn't.

**Head out WI as an investigative tool**

Thought many from mentioned facts were already acknowledged in the second half of the 19$^{th}$ century but, unfortunately, there were no practical implications until about 100 years later. There are two applications of water immersion: as an investigative tool and as a therapeutic maneuver. Both applications and based on the above mentioned redistribution of blood volume.

Research studies of Henry Gauer et al carried out in the 50s and 60s 20$^{th}$ century are considered the true beginning of water immersion as an investigative tool. It is ironic that the recent widespread interest in WI as an investigative tool received its impetus not from centuries of hydrotherapeutic practice but from the modern space program. It turned out that, due to the buoyant property of water, head-out water immersion mimics the weightless state. It has therefore been used in studying the influence of weightlessness on human body (2). Norsk et al emphasized the similarities between these two conditions with respect to renal excretion of sodium and water (3).

The number of research studies significantly increased in the 70s and 80s of 20 century, including studies on the effects of WI on renal function. Table 1 presents the number of papers listed in Pub Med that had been prepared by each of the mentioned research teams. All these papers discussed WI as an investigative tool.

In his excellent review Murray Epstein described the mechanisms by which head-out water immersion causes increase in urinary sodium excretion and therefore increase diuresis and decrease blood pressure. The main mechanisms are: inhibition of RAA system, increase of renal prostaglandins production and increase of natriuretic peptides (3).

He also proved, that the rise in urinary sodium excretion occurred no matter how big was sodium contents in diet. On the 10 mmol sodium excretion were of course smaller, than on the 150 mmol, but in compare to controls, in bath cases increase was significantly higher. This increase in urinary sodium excretion decreased after giving steroid, but was still significantly higher than in controls.

In healthy subjects WI induced enhanced diuresis and natriuresis at last partly by suppression of the RAA system, vasopressin secretion, the pituitary adrenal axis and by enhanced of natriuretic factors (4).

In hypertensive patients WI induced a significant decline in plasma renin activity, aldosteron and AVP which is quantitatively different from that observed in normals. As WI induced reduction of blood pressure was not significantly related to endocrine alterations, it seems, that factors other than PRA, Aldo and AVP are of importance in the maintenance of the particular types of hypertension (5).

In contrast to non-pregnant women, healthy pregnant women and women with EPH gestosis showed a significantly reduced increase in ANP secretion induced by WI (6). In diabetes type 1 and type 2 WI induced ANP secretion was significantly reduced as compared with normals. Despite a reduced response of ANP Secretion, the WI induced enhanced diuresis was a comparable magnitude both in normals and diabetics (7). In heart transplant patients ANP plasma levels were significantly higher than in normals and heart transplant patients. These results suggest presence of an infect physiological regulatory mechanism of ANP secretion in heart transplant patients (8).

To summarize the outcomes of the Kokot group, it can be concluded, that the importance of ANP secretion in the WI induced increase of diuresis may vary in different pathological states. However, first of all WI may be used as an nonaggressive investigative tool in patients with disturbances of the water electrolyte homeostasis, supplying information of endocrine organs, kidneys or nervous system in their pathogenesis.

Research studies into the WI model have been continued in the 21$^{st}$ century. Schou et al demonstrated, that suppression of generation of angiotensin 2 plays an important role in the natriuresis during WI (10). Valenti et al found that WI is associated with a reversible increase in urinary aquaporin 2 excretion (11). Recently Wang et al investigated the influence of WI on human motions and demonstrated that both the wrist and trunk activities were significantly decreased (12).

**WI as a therapeutic maneuver**

As mentioned before, WI was also used as a therapeutic maneuver in patients with excessive sodium and water retention.

The research has revealed the efficacy of WI as a therapeutic intervention for the variety of disease including essential hypertension (48 items in Pub Med), nephritic syndrome (9 items in Pub Med), decompensated liver cirrhosis (4 items in Pub Med), preeclampsia (7 items in Pub Med) and heart failure (38 items in Pub Med).

**Conclusion**

Presented in the article facts let to conclude, that WI was of great importance in development of nephrology as an investigative tool and therapeutic maneuver.

| Author group | Institution | 1st paper year | last paper year | Total papers (No) |
|---|---|---|---|---|
| M. Epstein et al | Jonhn Hopkins University (Baltimore) | 1971 | 1996 | 53 |
| F. Kokot et al | Medical University of Silesia (Katowice) | 1988 | 1998 | 49 |
| P. Norsk et al | University of Copenhagen/NASA | 1985 | 2011 | 43 |
| K. Miki et al | Naro Women's University (Japan) | 1986 | 2009 | 23 |
| J. E. Greenleaf at al | NASA | 1979 | 2003 | 25 |
| J. A. Krasney | University of Buffalo (USA) | 1982 | 1999 | 17 |
| J. P. O'Hare | Bristol Royal Infirmary (London) | 1985 | 2008 | 14 |
| O. H. Gauer | University of West Berlin | 1968 | 1978 | 7 |
| H. A. Koomans | University Medical Center (Utrecht) | 1989 | 2006 | 8 |

**Table 1: The number of papers on the effects of WI in humans published by the following author teams (according to PubMed, December 2017)**

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