TRAINING POOLS: THE IMPORTANCE OF THE RIGHT DEPTH

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Ref. training pools

1. SUMMARY

This article gives a summary of the professional contents-oriented reasons underlying the choice of the depth of training pools.

The depth required for the treatment of a patient depends on the purpose of the therapy and the methods used. The immersion depths required for initiating therapeutic effects on the posture and motion systems and creating cardiovascular changes are stated below.

A number of hydrotherapy methods will be discussed in relation to the required depth. Several alternatives for meeting the existing requirements with regard to an adequate water depth in an optimal way will be considered.

2. INTRODUCTION

In literature about aquatic therapy little attention is paid to the requirements the pool has to meet[1, 2, 3]. The motives underlying the choice in favour of a certain facility or a certain pool dimensioning are often dictated by external (national) regulations. A professional contents-oriented motivation was not found in the recommendations in the literature studied.

Nevertheless the dimensioning of therapy pools is a factor of considerable importance. Eventually not only the water surface, but also the pool depth and the differences in the floor level are decisive for the functionality of a pool.

3.1 DIFFERENCES IN LEVEL

Obviously all patient categories using a therapy pool need an appropriate water depth for their exercises[4].

The combination of the advisable immersion depth, the patient's and therapist's physical heights, the basic position and aquatic therapy-methods will determine the choice of the required depth in a pool.

Since patients in general will perform their exercises in an upright position, the standing and walking patient will be the focus of attention during the process of surveying the desired depths.

3.2 DESIRED IMMERSION DEPTH

This factor is usually mentioned in the context of post-operative and post-traumatic walking training for the purpose of muscle function training, improving neuromuscular control, training arthro-kinetic responses, stretching collagen connective tissue and improving the aerobic endurance.

The choice of depth determines the reduction of the axial load on submerged structures[5,6]. This reduction is caused by the buoyancy of water. According to Archimedes' principle a wholly or partly submerged body experiences an upward force, equal to the weight of the displaced water volume. Buoyancy compensates for gravitation and causes the reduction of weight which is experienced during a stay in the water.

The displacement increases as the patient is immersed more deeply. In case of persons with normal proportions a percentage of the physical height can be related to a certain anatomical structure. In table 2 this relation is shown by Harrison and Bustrode[6] for patients standing in water of various depths. In this table the patient's absolute height is not relevant.

3.3 TISSUE COMPOSITION

The percentage of weight borne in connection with the immersion depth is showing a dispersion, depending on the patient's exact tissue composition (see table 1).

In case of a physical disorder both the density and the amount of a certain type of tissue may change. This affects the percentage of the body weight borne!

tissue	density	% men	% women
muscle	1.06	45	36
bone	0.91	15	12
fat	1.5	15	22

Table 1: Average density of certain tissues in untrained, healthy persons.

The difference in tissue composition between men and women accounts for the differences between the sexes as mentioned in table 2. Harrison et al.[7] have measured reactive forces at various immersion depths, during both standing and walking, and have based their conclusions on these measurements about the effect of walking speed on the effectively borne percentage of weight.

% submerged body:	submerged to:	% borne weight, men	% borne weight, women
14	knee	84	84
39	hip	63	56
48	pelvis rim	54	47
68	pit of the stomach	35	26
88	clavicle	13	12
94	chin	8	8

Table 2: Percentage of weight borne in relation to the immersion depth, in an upright position, modification of Harrison & Buistrode[6].

Depending on the immersion depth the percentage of the weight borne may vary from 8 % up to 84%. A percentage over 8 % is possible, when the head is submerged as well. In the load building practice this is rather seldom.

As a minimum depth, before moving on to dry therapy, the upper leg depth is commonly used, corresponding to a load of 65 - 70 %.

In case of a 190 cm tall adult, a weight reduction between 90 % and 10 % requires water depths of 80 cm to approx. 170 cm. The same calculation for a 100 cm tall child requires depths between approx. 30 and 70 cm. (Children have a relatively large head).

Therefore a well-balanced increase of the axial load requires an adjustable water depth.

3.4 MUSCULAR ACTIVITY

Muscular activity during standing and walking activities is different in water than it is on dry land. Under the influence of reduced weight the - dorsal - extension musculature activity is less than it is on dry land. Both the oxygen consumption[8, 9] and the electro-myographic signal[10, 11] are less. Furthermore EMGs show a depth-related, ventral displacement of the muscle activity while standing still. Additionally the diagram 1 shows that no muscle signals can be measured during a suspended vertical position, using buoys, the subject is passive and relaxes (Mitarai et al 1981).

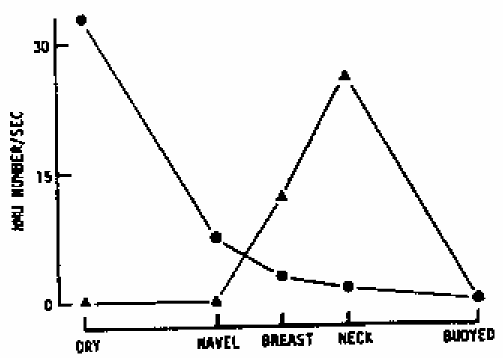


Diagram 1: Changes of total number of active NMU in the soleus (filled circle) and the tibialis anterior (triangle) with increasing water immersion.

This displacement can be beneficial for relieving hypertonic extensor muscles and for facilitating ventral muscles e.g. the paretic ankle dorsal flexion in case of hemiplegia.

3.5 CARDIOVASCULAR SYSTEM

Depth also plays a part in the load of the cardiovascular system. The hydrostatic pressure (in water) increases linearly with the depth. This means that every object that is wholly or partly submerged in water, is subject to a pressure difference.

The effects of this pressure difference on and inside the human body are especially clear in the cardiovascular system[12, 13], as shown in table 3.

	air	hip deep	chest deep	chin deep
cardiac output L/min.	5.1	5.7	7.4	8.3
pulsatory volume ml.	67	78	110	120
heart frequency/min.	76	73	68	70

Table 3: Adjustment of heart frequency, pulsatory volume and cardiac output in standing persons, during immersion at 35º C, according to Fahri & Linnarson[12].

Because of the increasing ambient pressure the circulating fluids are redistributed, increasing the central venous volume, among others the volume of the right atrium. The volume displacement and the subsequent pressure increase are the main reasons for a series of compensation mechanisms for the benefit of the volume homeostasis[13].

Initially these mechanisms are mediated in a neuronal way; the ortho-sympathetic system is inhibited[14, 15, 16]. This inhibition causes bradycardia and generalised vasodilatation[12, 17, 18]. The vasodilatation leads to an increased saturation of the musculature and connective tissue[19], which is a precondition for the improvement of the local trophic level or level of metabolism.

Improving the trophic condition of tissues as a preparation for the training is one of the fundamental principles of physiotherapy.

The main blood displacement is taking place when the major abdominal veins are submerged, i.e. in a water depth of approx. 105 to 135 cm in case of an adult standing upright. In paediatrics this depth changes accordingly.

Immersion should be performed gradually, especially when sudden and/or excessive strain of the myocardium could involve a risk, e.g. after a recent myocardial infarction[20, 21].

3.6 RESISTANCE

When the person is moving, the resistance noticed in the water is higher than the air resistance. This resistance, as a consequence of the viscosity and the density, depends mainly on the speed of the movement: resistance increases with the speed squared. But resistance also depends on the hydrodynamic form of the person and the frontal plane or surface[22, 23, 24]

During walking training the frontal surface increases when the patient is submerged deeper. Therefore the immersion extent partially determines the resistance during a movement and the required muscle capacity (and thus the consumption of energy) at a certain speed of movement.

However, speed is the determining factor. According to McWaters[25] the resistance during aqua-jogging, i.e. walking in the water using a special buoyancy aid (wet-belt) without touching the bottom, is 5 to 43 times higher than when walking on dry land when comparing walking at different speeds.

3.7 ENDURANCE

Moving in water is increasingly used as a means of training aerobic endurance. In water large groups of muscles can be used rhythmically and dynamically, with low static components. The occurrence of local strain is thereby diminished and the oxygen transportation system is not overloaded[26, 27, 28]. Many muscles are used, and even at a relatively low speed there is a high external load[29]. This high external load is converted into a high heart rate while walking in the water, as compared to walking on dry land, as shown in diagram 5 (Whitley & Schoene[29]).

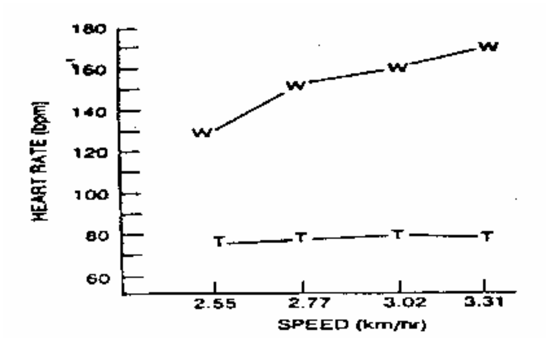


Diagram 5.

These points, combined with the diminished gravitational axial load and therefore the decreased mechanical impact at the lower extremities and trunk, form the rationale for many medical fitness programmes and sports rehabilitation activities in water[30, 31].

Again, depth is playing a crucial role. On the one hand a certain depth is demanded for achieving the appropriate water resistance for the targeted energy consumption. On the other hand the friction between the feet and the bottom, which is necessary in order to overcome the speed-related water resistance, decreases as depth increases.

Nicholas & Gleim[32] have found that the optimum depth to gain both advantages is at the level of the proximal upper leg, i.e. approximately at 60 to 90 cm for adults. For children, depths between 40 and 70 cm are appropriate.

3.8 PHYSICAL HEIGHT

The necessary water depth for a patient with a certain body height is first and foremost related to the therapeutically desirable immersion depth. Other vital criteria are the individual's swimming skills and/or possible fear for water.

The equilibrium is changing drastically when standing in the water up to approx. the 11th thoracic vertebra (Th 11), at some 70 % of the physical height[5] (see Figure 1).

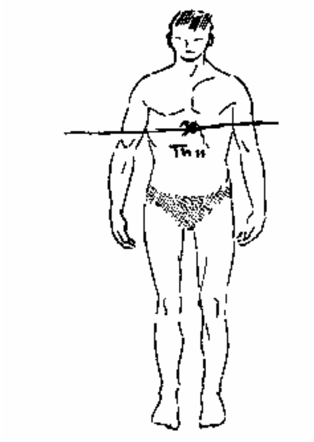


Figure 1.

This is also important where the therapist is concerned. The stability needed to be able to be a fixed point for the patient becomes insufficient when the water level is over Th 11. Using the Bad Ragaz Ring method, for example, the therapist is the fixed point for the patient, who is moving through the water in relatively closed chains. Particularly in this method, also friction between floor and therapist's feet is another important factor.

4.1 BASIC POSITION and METHODS

The upright basic position and the importance of the water depth have been analysed already. During aquatic therapy also other training positions are used, e.g. chair / squatted, the oblique supine position, sitting on the ground and recumbent posture.

One or several of the mentioned positions are practised in the training methods used in aquatic therapy. The most commonly used methods will be discussed below in relation to position and water depth.

4.2 HALLIWICK

The Halliwick method originally was a swimming method for persons with a disability. The founder J. McMillan, a Canadian fluid mechanics engineer, also refined the fluid mechanical features, affecting the swimmer's balance into principles used in physical therapy. This concerns the use of flow conditions, volume and mass displacement, and waves[5, 33, 34].

The Halliwick method uses all positions, which in fact requires a variety of water depths in order to enable an optimal application of the method. In figure 2 turbulent flow is used to disturb the equilibrium of the patient sitting in a squatted position.

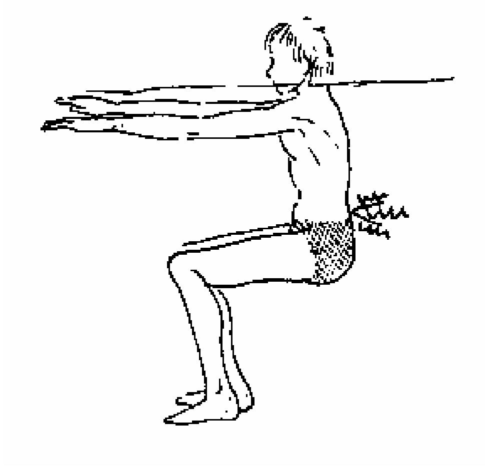


Figure 2.

From the therapist's point of view, the depth should be around T11. This means that the required pool depth is between 120 and 140 cm.

4.3 BAD RAGAZ RING METHOD

The Bad Ragaz Ring method is a method in which the patient moves through the water. The patient is lying in a dorsal position using buoyancy aids and moves his or her limbs and trunk. The implementation of principles from proprioceptive neuromuscular facilitation (PNF) have been included to be used in three-dimensional patterns (Figure 3). Recent developments, using mask and snorkel, have made it possible to work in prone.

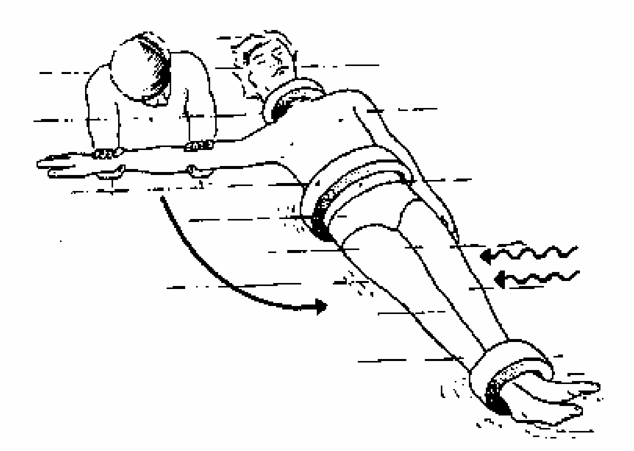


Figure 3.

The physiotherapist is the - absolute or relative - fixed point in the kinetic chain[1, 2, 3]. The ergonomically sound position of the therapist is particularly important for this method. It is recommended that the therapist is standing in breast deep water. This depth allows the therapist to work in an upright position with sufficient weight to stand firmly on the bottom during the therapy[2]. To be more precise, levels around T11, again, provide a better stability in combination with a good body posture. Depth typically varies between 120 and 140 cm.

4.4 WATSU

Also in Watsu the correct depth is important. Watsu is a method of relaxation in the water, which is based on meridian stretching, as it is applied in Shiatsu. The therapist manually supports the patient, who is lying on his/her back, and rocks and swings him/her gently in the water[35] (Figure 4). Since the therapist sits in a wide squatted position that enable to make large rotational movements, the preferred depth is between 100 and 120 cm.

Figure 4.

4.5 CONVENTIONAL AQUATIC THERAPY

A part of the exercise repertoire in conventional aquatic therapy is performed while the patient is lying down on a stretcher (Figure 5). One could use a system, hanging down from the edge of the pool or railing, but it is also possible to place a stretcher on the bottom of the pool. A minimum water depth from approx. 50 cm offers an opportunity for training in a semi-sitting position, while the patient's head is supported and the extremities and the trunk are submerged for the purpose of the exercises[3].

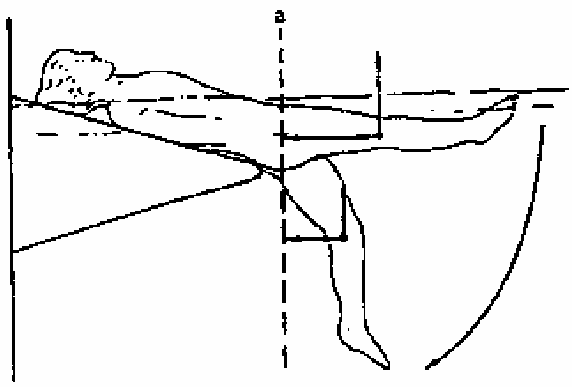


Figure 5.

4.6 AQUA-JOGGING and SWIMMING

At present training the aerobic endurance as part of medical fitness is the focus of attention. Aqua-jogging or deep water walking is a commonly used method (Figure 6). This can only be performed in water with a depth of 180 cm minimum.

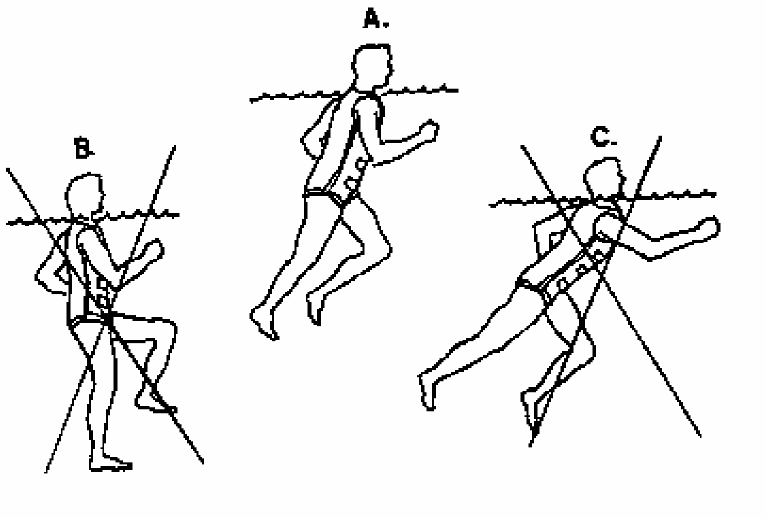


Figure 6.

In principle swimming is done at a water depth where the patient's feet are not touching the bottom, i.e. from approx. 50 cm onward. There is no maximum depth.

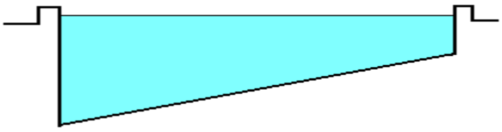
The preparation for swimming (water adjustment and rotation control) is performed at a depth where the patient is able to stand firmly and where the vertical rotation is not obstructed by the bottom[5, 36]. Since children are frequently supported by their instructors, required depths for both children and adults are alike: 100 to 140 cm.

5.1 THE BOTTOM

It can be concluded from the above that the required depths vary between 40 cm and 180 cm. A much used depth is the depth around T11. In fact, the 120 to 140 cm section of the pool needs to be rather spacious, especially when group work is being done.

Differences in level can be realised by using a sloping bottom, a bottom comprising horizontal sections separated by slopes or steps, or an adjustable bottom. Most therapy pools have a limited surface.

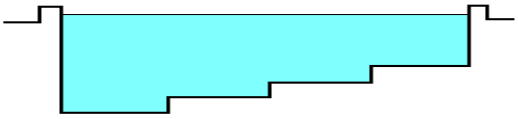
5.1.1 A sloping bottom



A sloping bottom normally has a gradient van 6 to 7%[37, 38]. This seems to be a minor slope, but walking right across the width of the pool even a 5% incline has an effect of walking with a leg's length difference of 1,5 cm[1]. Therefore a 3% slope is often recommended[39]. Especially in case of group activities an additional risk could be that the swimmers drift towards part of the pool which is deeper, or too deep, without noticing, because of the moving water[5, 40].

The gradient limits only allow a slight difference in level, considering the limited dimensions of a therapy pool.

5.1.2 A bottom with various fixed depths



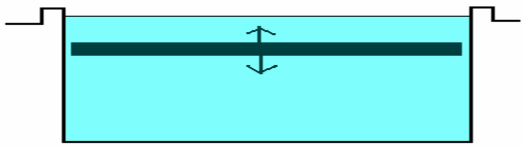
A bottom comprised of horizontal sections at various levels meets the requirements for creating both a minimum and a maximum depth.

The difference in level will have to be bridged by slopes or the use of steps.

Differences in level realised through slopes or steps are dangerous and must be clearly marked[38]. Slopes and steps are not utilised and reduce the effective surface area[40].

The amount of surface area is important in group activities, normally consisting of various ways of walking. The width of the patient's lane is approx. 1 m. Slopes or steps are especially limiting for adequate group therapy.

5.1.3 An adjustable bottom



In current Dutch directions for therapy pools in institutions adjustable bottoms are mentioned as a means to attune the entire surface area to relatively homogeneously composed groups[38] and to create a variety of depths in therapy pools of limited proportions[38, 41]. Where there is no possibility to create sufficient floor surface to facilitate the motion activities of each of the target groups, because of the pool's dimensions, an adjustable bottom is recommended[42].
This is considered to be the ideal solution[3].

6 CONCLUSION

From a professional contents-oriented point of view the generally required depths vary between approx. 40 to 160 cm. When aqua-jogging is one of the main activities the minimum depth of a pool should be at least 180 cm.

In addition the bottom should have sufficient horizontal surfaces for the purpose of group activities. A sloping part should provide an opportunity to vary the axial load, or alternatively provide patients with different body heights with an equal axial load.

In order to incorporate all required depth functions in one pool, an adjustable bottom seems to be the best option. Ideally this bottom should also be able to gently slope, to accommodate patients with different heights and weight bearing needs in the pool at the same time.

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