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The Physical and Scar-Related Effects of Short Term Passive Hydrotherapy Versus Aquatic Exercise Versus Usual Care Therapy In An Adult Burn Population: An Explorative Study

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ABSTRACT

Background: Hydrotherapy is a well-known method in the treatment of various diseases, but its efficacy remains unknown after burns. The purpose of this controlled clinical trial was to examine the effect of an existing scar-related local treatment (passive hydrotherapy), and an alternative physical activity in water (active hydrotherapy) and compare these to usual care therapy (physical therapy, pressure and silicone therapy) in an adult burn population.

Methods: Forty-two patients were allocated into one of three groups: 3-weeks treatment in a spa resort (passive hydrotherapy=PHT); or 3-weeks aquatic exercise (active hydrotherapy=AHT); or only usual care therapy. Therapists and assessors were aware of treatment allocation. Both intervention groups continued usual care therapy during the hydrotherapy intervention. Physical and scar-related outcome measures were assessed at baseline, during intervention and at follow-up until 3 months. Physical parameters included pulmonary function, hand grip strength, functional status and joint range of motion. Scar sites were evaluated for sensation, color, transepidermal water loss and elasticity. Scars were also subjectively assessed using the Patient and Observer Scar Assessment Scale (POSAS) questionnaire.

Results: In the AHT group a significant increase in hand grip strength was found. In the PHT group hand grip strength decreased temporarily during intervention but returned to baseline at 3-month follow-up. In all groups there were significant improvements in redness and POSAS vascularity score over time, although there was a temporary increase in redness and vascularity during the intervention in the PHT group. A significant lower itching score was found in the PHT group during intervention.

Conclusions: This was the first study that investigates the short term effects of various applications of hydrotherapy in burn patients. We can conclude that the small changes observed in some physical and scar related parameters are promising and more research in this field is indicated.

Trial registration: The study was approved by the Ethical Committee of the University Hospitals of Leuven (Belgium) with protocol number ML4626. Ethical Committee of the University Hospitals of Leuven (Belgium), ML 4626 with Belgian number B32220073057. Registered 7 March 2008, https://www.uzleuven.be/en/ec.

BACKGROUND

Over the past 40 years mortality after burns has substantially decreased in industrialized countries due to the development of comprehensive burn centers integrating the associated advances in treatment. This has resulted in a shift of focus from mortality towards the functional outcome of burns and the need for extensive rehabilitation including physical and occupational therapy and psychological support. The most frequent complications after burns are deconditioning, muscle weakness, hypertrophic scarring, pain, itching, psychological and social impairments [1].

Physiotherapy can thus play an important role in the acute treatment and rehabilitation process of burn patients and includes joint mobilization, positioning, splinting, massage therapy, pressure and silicone therapy, exercise therapy and cardiopulmonary training [2,3]. Of all non-invasive topical scar treatments, pressure therapy and silicone gel sheeting are the most widely endorsed and evidence supported interventions and in fact applied in practice [4–7]. Mobilization, positioning and splinting are also extensively used in burn treatment, although no RCTs and CCTs are found [7]. Massage therapy in hypertrophic scarring is moreover recommended in burn after care and has a positive effect on scar pliability, pain and pruritus [7–11]. Use of moisturizers and lotions are widely acknowledged scar treatments and could have an effect on itching, although the ideal composition of moisturizer is unknown [7]. In children with burns various studies have shown positive effects of exercise therapy to improve functional outcome, muscle strength and pulmonary function [12–15]. In adults however few randomized controlled trials are available particularly for strength and pulmonary function although both are needed to actively take part in daily life.

Hydrotherapy is a well-known method in the treatment of musculoskeletal conditions, neurological disorders, cardiovascular diseases, pulmonary dysfunction, etc. [16]. The use of water produces diverse effects on various body systems depending on the water temperature [16]. A passive form of hydrotherapy or balneotherapy is a term generally applied to various forms of spa treatment and refers to the medical use of spas. Balneotherapy produced significant results in functional condition and quality of life in patients with rheumatoid arthritis, dermatologic disorders and chronic venous insufficiency [17–19]. In France in particular balneotherapy is a common method to administer physical therapy and topical burn scar treatment [20]. This consists of a 3-week treatment in a spa resort specialised in skin problems and diseases and is reimbursed twice a year but its efficacy in burn scarring had never been actually assessed.

An active form of hydrotherapy or aquatic exercise provides several therapeutic benefits as compared to land-based exercise. Buoyancy and hydrostatic pressure counteract gravity and create an environment with low joint loading and variation in muscle resistance during movement due to high levels of viscosity in water. This leads to an enhanced venous and lymphatic return and reduces swelling. Moreover, this decreases the risk of injury and improves strength and endurance [21].

This might provide a more effective and attractive medium to develop physical fitness in several patient groups while at the same time including components of spa therapy. Furthermore it could make use of local facilities and not require patients to travel sometimes long distances to a specific treatment center.

In collaboration with the Belgian Burn Foundation, we had the opportunity to go with a group of patients with burn scars (fully healed) to a thermal cure centre in France for a unique 3-week period. In comparison to the 3-week intervention in France, we wanted to organize a 3-week treatment in a regular swimming pool at home in this case in Belgium, so called aquatic exercise. Aquatic exercise was also organised for a 3-week period, but in small groups, depending on the availability of the swimming pool. Aquatic exercise is an interesting alternative nearer to family and normal daily social life. Water is the main feature in both treatments although the active hydrotherapy includes active exercises and physical training.

Therefore, the purpose of this study was to examine the effect of an existing scar-related local treatment (passive hydrotherapy), and an alternative physical activity in water (active hydrotherapy) and compare these to usual care therapy in an adult burn population. Both treatments examined are considered as complimentary to normal care and not as a replacement or alternative.

METHODS

Study design

The study design was a non-randomized controlled trial. Data were collected between April 2008 and May 2014. Based on the availability and practicality for patients and as well as the organization of therapy intervention, patients were allocated into one of three groups either completing a 3-week treatment in a spa resort (passive form of hydrotherapy =PHT) in Avène (France) or three weeks of aquatic exercise (active form of hydrotherapy =AHT) at home in Leuven (Belgium) or only the usual care therapy without additional hydrotherapy (=UCT). Therapists and assessors were aware of treatment allocation. Both intervention groups continued the usual care therapy during the hydrotherapy intervention.

Study population

Patients recruited, met the following inclusion criteria: healed wounds of at least second degree deep burns, a total body surface area burned (TBSA) ranging from 5 to 40%, scars in active phase of healing and at least one of the extremities (with the burn scar crossing a joint) was involved. Patients younger than 18 years of age or with psychiatric history, central neurological illness or peripheral paralysis were excluded.

Scar sites

At most three scar sites were evaluated for each patient. The test site boundaries were carefully measured, noted in the patient chart, captured with digital photography and referred to during each visit for defining exact location for assessment.

Intervention

- *PHT*

All patients in this group took part in PHT during a single 3-week period, 6 days a week. The duration of this treatment was based on an accepted protocol in France reimbursed by insurance companies. The treatment time varied between 3 and 4 hours per day. Patients were individually treated and all treatments were administered by dermatologists and specialized therapists of the center in Avène. An additional file shows detailed information on the PHT program [see Additional file 1]. During the 3-weeks stay, all patients were instructed to continue their standard after care of burn scar treatment (pressure garments, hydration and physiotherapy). A team of Belgian physiotherapists guaranteed continuation of usual care on site.

- *AHT*

Patients in the second group performed AHT in a classic chlorinated swimming pool (27.8°C; 25m * 13.33m, depth 1.28m - 3.5m) during 3 weeks, 3 days a week. A session lasted 1 hour and the interval between 2 training sessions was at least 24 hours. Patients were treated in groups of 3 persons. The training sessions were supervised by one aquatic training expert and one physiotherapist. Sessions were designed to stimulate the patient to be active in water by actual swimming, aquajogging and underwater cycling. An additional file gives detailed information on the AHT program [see Additional file 2]. During the AHT, all patients were instructed to continue their standard after care of burn scar treatment (pressure garments, hydration and physiotherapy).

- *UCT*

The UCT did not perform any additional treatment. They continued their usual care of burn scar treatment (pressure garments, hydration and physiotherapy).

Measurement procedure, outcome measures and measurement tools

Table 1: Test battery and evaluation moments

	pre	w1*	w2*	w3	+2w	+3m
(1) pulmonary function	x			x	x	x
(2) hand grip strength	x			x	x	x
(3) joint motion	x	x	x	x	x	x
(4) sensory testing	x	x	x	x	x	x
(4) color assessment	x	x	x	x	x	x
(4) TEWL measurement	x	x	x	x	x	x
(4) elasticity measurement	x	x	x	x	x	x
(4) POSAS questionnaire	x	x	x	x	x	x
(5) functional status	x			x	x	x

*no evaluation for patients of usual care therapy (UCT)

The outcome measures were physical and scar-related parameters. Physical parameters included pulmonary function, hand grip strength, functional status and joint range of motion. To stabilize cutaneous blood flow, all patients were asked to remove pressure garments at least 30 minutes before measurements were started. Table 1 presents the measurement procedure and test battery. At baseline (pre) all parameters of the complete test battery were registered in the following order (to reduce bias).

(1) The maximum values for forced expiratory volume in one second (FEV1; expressed in l/sec) and forced expiratory vital capacity (FVC; expressed in l) were registered. Patients were instructed to perform two (successful) tests using the RDSM Spirotel® [22].

(2) For hand grip, tip and key pinch strength, three trials were performed using the North Coast Dynamometer® (Jamar Dynamometer) and North Coast Hydraulic Pinch gauge® (expressed in 0.1 kg). The best scores of the dominant hand were recorded [23].

(3) Mobility was registered in joints with burn-related limitations in range of motion for lower and upper extremities and neck rotation, both actively and passively (expressed in degrees) using a goniometer following standardized guidelines. Head extension, head lateroflexion and mouth-opening were measured using a tape measure (expressed in 0.1 centimeters) [24].

(4) Based on patient complaints and/or observer, one to three scar sites per patient were selected for scar assessment. Scar sites were evaluated for sensory testing (using 5 piece hand kit Semmes-Weinstein monofilaments), color (using Minolta Chromameter CR300®; expressed in L*, a* and b*) [2, 25], skin barrier function with transepidermal water loss measurement (TEWL) (using DermaLab®; expressed in $g/m^2/h$) and elasticity (using DermaLab®; expressed in MPa) [26]. The Patient and Observer Scar Assessment Scale (POSAS) questionnaire was completed for each scar site. This scale consists of both an observer and a patient component and contains the most frequently used scar features. On a 10-point rating scale, the observer scores vascularity, pigmentation, thickness, relief (defined as surface roughness), pliability, surface area and overall opinion. Whereas the patient scores color, pliability, thickness, relief, itching, and pain. The lowest score '1' corresponds to the situation of normal skin (normal pigmentation, no itching etc). The highest score '10' indicates the worst imaginable scar or sensation [25–28].

(5) Evaluation of functional status using the 6-minute walk test (6MWT); expressed in distance (m) was performed at the end of an evaluation session [29].

After one week (w1) and after two weeks (w2) of intervention, evaluation of mobility and scar assessment were repeated. At the end of the intervention (after three weeks) (w3), 2 weeks (+2w) and 3 months after termination of intervention (+3m) all physical parameters and scar assessments (complete test battery) were made.

The UCT was evaluated at three time points only (pre, w3, +3m) using the complete test battery.

Statistical analyses

Kruskal-Wallis tests were used to compare baseline values between the groups. Means and 95% confidence intervals (95% CI) were obtained from a general linear model for longitudinal measurements with a covariance matrix taking into account the presence of multiple scars within a patient and the repeated measures over time. A random patient effect was used to model the correlation between scars from the same patient. For the repeated measures over time an unstructured covariance matrix was used. If the distribution of the model residuals was right-skewed, the outcome was log-transformed (natural logarithm), but figures with least-squares means were created after back-transforming to the original scale (in which case they refer to geometric means and their 95% CI). Given the non-randomised character of the study, two different models were used. To evaluate in each group the evolution over time and compare this evolution between the three groups (PHT, AHT and UCT), a first longitudinal model was fit including the baseline measurement as outcome variable. Inclusion of the baseline measurement as a response also allowed the visualization of this evolution including the baseline measurement. Since timepoint specific comparisons can be biased by differences at baseline, in a second model the analysis was restricted to post-baseline values which were compared between the three groups. The baseline value and the age of the scar were added as covariates in this model, their effects being allowed to vary over time (by including interactions with time). Note that given the small number of subjects per group, it was not possible to adjust for more confounders in the statistical analysis. The considered confounders were determined prior to the analyses.

All analyses were performed using SAS software, version 9.2 of the SAS System for Windows. The level of statistical significance was set at 0.05.

RESULTS

In total 42 patients were recruited from six Belgian Burn Centers and agreed to participate in this study with fourteen patients in each intervention group (PHT, AHT and UCT). In total 93 scars were measured in 42 patients. Three scar sites were located on the face and 12 sites on the trunk. Fourteen scars were situated on the upper arm, 20 on the forearm and 13 on the hand. Eighteen sites were located on the upper leg, 9 on the lower leg and 4 on the foot.

Table 2: Patient and scar related characteristics

	PHT	AHT	UCT
n	14	14	14
age ± SD (yrs)	36.2 ± 10.69	37.3 ± 10.21	39.4 ± 16.51
(min; max)	(19.0; 56.0)	(22.0; 52.0)	(19.0; 67.0)
female/male	4/10	2/12	4/10
BMI ± SD	27.0 ± 4.33	24.8 ± 2.97	25.7 ± 4.88
(min; max)	(18.9; 34.5)	(20.6; 29.7)	(19.8; 36.7)
TBSA (%)	24.5 ± 12.9	25.9 ± 17.3	19.1 ± 14.6
n scar sites	33	30	30
scar age ± SD (mo)	5.5 ± 2.96	6.0 ± 4.37	5.0 ± 2.09
(min; max)	(1.0; 11.5)	(1.5; 15.0)	(3.0; 9.0)
scar locations (upper body [1] – lower body [2] – both upper and lower body	6 – 3 – 5	7 – 4 – 3	9 – 4 – 1
drop-out	7.14%	0%	†
intervention compliance	92.87%	100%	†
loss to follow-up	0%	7.14%	0%

Abbreviations: PHT: Patients of passive hydrotherapy; AHT: Patients of Active Hydrotherapy; UCT: Patients with Usual Care Therapy

†UCT was individually determined by burn surgeon following the policy of the burn center, although compliance was not registered in detail

[1]upper body includes always at least one upper extremity and/or head and/or chest

[2]lower body includes always at least one lower extremity… and/or abdomen and/or back

Patient-, scar- and therapy-related… characteristics of all groups are reported in Table 2. Age, BMI and scar age were comparable in the three groups. One patient terminated the PHT after two weeks of treatment for personal reasons. All patients of the AHT group completed the 3-week training. One patient of the AHT was lost at 3-month follow-up.

Table 3 shows the baseline comparisons between groups. Most scar-related outcome measures at baseline showed significant differences between groups. No statistically significant ($p>.187$) differences were observed between the three groups in the physical variables at baseline. In the results of the between-group analysis, all plots were restricted to post-baseline values. The baseline value, the (scar) age and sex were added as covariates in the model.

There was no evidence for a difference between the groups at baseline and no clinical relevant within-group evolution for pulmonary function, tip and key pinch strength, joint motion, scar elasticity, sensory testing, various items of patient scale of POSAS (pain, color, stiffness, thickness, irregularity and overall opinion) or items of the observer scale (pigmentation and pliability). No detailed results from these analyses will, therefore, be presented further.

Physical parameters

- 6-MINUTE WALK TEST (Figure 1)

The 6MWT was improving over time in the three groups and significantly in AHT ($p=.0037$) and UCT ($p=.0304$). There was no difference between all groups, either in evolution ($p=.3856$), or in post-baseline values after correction for age, gender and baseline value.

- HAND GRIP STRENGTH (Figure 2)

Hand grip strength increased over time in the AHT group ($p=.0105$). There was also a significant change in the PHT group ($p=.0433$): the hand grip strength decreased during the 3-week intervention and increased again at 3-month follow-up. In UCT the hand grip strength remained unchanged ($p=.7650$). The evolution was significantly different between the AHT and UCT ($p=.0433$) and between the PHT and AHT ($p=.0253$). The latter difference in evolution resulted in a higher hand grip strength after 2 weeks in the AHT compared to the PHT ($p=.0089$), after correction for the baseline value, gender and age.

Table 3: Descriptive information of baseline comparisons between the three groups (M ± SD)

	PHT	AHT	UCT	p-value
redness (a*) (range: 5 to 25; SEM = 1.30)[27]†	16.3 ± 3.07	16.5 ± 3.50	17.6 ± 1.95	0.21
TEWL ($g/m^2/h$) (range: 0 to 65; SEM = 2.76)[25]†	15.6 ± 10.20	15.0 ± 6.72	22.8 ± 9.81	0.003*
elasticity (MPa) (range: 0 to 15.625; SEM = 0.89)[25]	11.1 ± 3.53	11.1 ± 3.41	11.3 ± 3.91	0.87
POSAS patient - pain††	3.1 ± 2.57	2.4 ± 2.09	2.0 ± 2.06	0.093
POSAS patient – itch††	5.3 ± 3.16	4.4 ± 2.99	3.2 ± 2.28	0.030*
POSAS patient – color††	7.8 ± 1.82	7.2 ± 2.21	6.0 ± 2.74	0.024*
POSAS patient – stiffness††	7.6 ± 2.35	6.0 ± 2.60	5.9 ± 2.21	0.007*
POSAS patient – thickness††	6.8 ± 1.89	6.2 ± 2.48	5.6 ± 2.81	0.17
POSAS patient – irregularity ††	6.6 ± 2.26	5.8 ± 3.18	5.5 ± 2.86	0.37
POSAS patient – overall††	7.7 ± 1.53	6.3 ± 2.51	5.1 ± 2.82	<0.001*
POSAS observer – vascularity ††	6.6 ± 1.97	6.0 ± 1.97	5.5 ± 1.62	0.06
POSAS observer – pigmentation††	6.3 ± 1.90	5.1 ± 2.16	4.0 ± 1.57	<0.001*
POSAS observer – thickness††	6.3 ± 1.96	5.4 ± 2.11	4.9 ± 1.85	0.024*
POSAS observer – relief ††	6.0 ± 1.77	4.9 ± 1.87	3.8 ± 1.52	<0.001*
POSAS observer – pliability ††	6.6 ± 1.87	5.2 ± 2.17	5.1 ± 2.12	0.007*
POSAS observer – surface††	6.1 ± 1.65	5.1 ± 1.80	3.1 ± 1.37	<0.001*
POSAS observer – overall††	6.5 ± 1.64	5.7 ± 2.00	5.0 ± 1.55	0.005*
6MWT (m)	515.1 ± 78.10	547.6 ± 84.78	548.5 ± 107.24	0.53
FEV1 (l)	3.8 ± 1.01	3.7 ± 0.87	3.6 ± 0.87	0.81
FVC (l)	4.6 ± 1.14	4.6 ± 0.80	4.3 ± 0.99	0.60
handgrip strength∆ (kg)	39.3 ± 14.97	34.9 ±14.27	40.0 ±12.43	0.65
pincet pinch strength ∆ (kg)	6.7 ± 2.97	5.6 ±1.57	5.7 ± 1.49	0.76
key pinch strength ∆ (kg)	8.0 ± 2.50	6.6 ± 2.04	7.2 ± 1.44	0.19

Abbreviations: PHT: Patients of Passive Hydrotherapy; AHT: Patients of Active Hydrotherapy; UCT: Patients with Usual Care Therapy

† based on clinical experience and/or results of this study

†† range 1 to 10

∆ dominant side

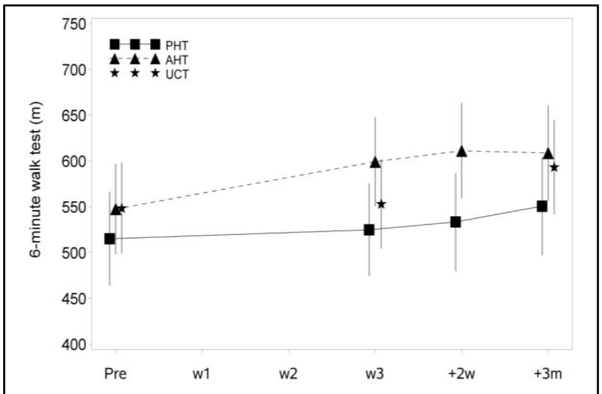

Figure 1: Evolution of 6-minute walk test.

PHT = patients of passive hydrotherapy; AHT = patients of active hydrotherapy; UCT = patients with usual care therapy

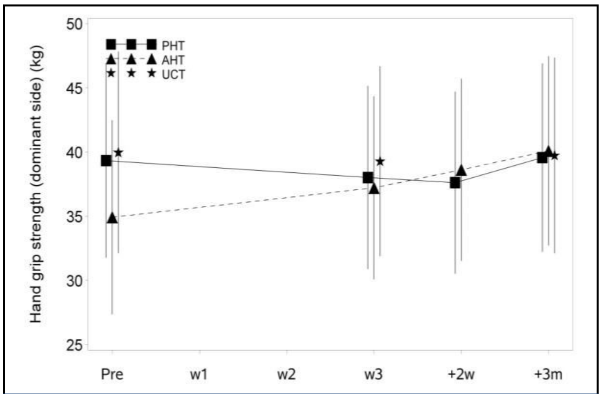

Figure 2: Evolution of hand grip strength.

PHT = patients of passive hydrotherapy; AHT = patients of active hydrotherapy; UCT = patients with usual care therapy

Table 4: Pairwise comparisons of mean a*value, TEWL value of scar sites (after correction for baseline values and scar age), post-baseline itching (POSAS – patient scale), post-baseline vascularity (POSAS – observer scale), post-baseline relief (POSAS – observer scale) and post-baseline global opinion (POSAS – observer scale)

		PHT	AHT	UCT	p-value	PHT vs AHT	PHT vs UCT	AHT vs UCT
a*	w1	15.8 (15.0;16.7)	15.9 (15.2;16.7)		0.86	0.86	.	.
	w2	16.6 (15.9;17.2)	15.8 (15.0;16.5)		0.12	0.12	.	.
	w3	18.8 (17.6;20.0)*	15.7 (15.0;16.5)	16.5 (15.7;17.3)	0.000	<.000	0.002	0.15
	+2w	16.9 (16.2;17.6)	15.6 (14.9;16.4)		0.019	0.019	.	.
	+3m	15.7 (14.9;16.4)	14.8 (14.0;15.5)	14.1 (13.2;14.9)	0.014	0.10	0.004	0.22
TEWL	w1	14.4 (12.4;16.8)	15.9 (13.6;18.6)		0.40	0.40	.	.
	w2	14.7 (12.5;17.3)	14.8 (12.4;17.7)		0.95	0.95	.	.
	w3	16.7 (14.1;19.7)	14.3 (12.1;17.0)	13.1 (10.9;15.6)	0.15	0.21	0.06	0.46
	+2w	15.5 (13.2;18.3)	14.4 (12.1;17.0)		0.51	0.51	.	.
	+3m	16.7 (13.7;20.4)	11.8 (9.5;14.5)	13.3 (10.7;16.5)	0.05	0.017	0.13	0.44
Itching	w1	2.6 (1.8;3.4)	4.0 (3.2;4.8)		0.014	0.014	.	.
	w2	2.2 (1.5;3.0)	3.3 (2.5;4.1)		0.05	0.051	.	.
	w3	2.4 (1.6;3.1)	3.1 (2.3;3.8)	4.1 (3.3;4.8)	0.007	0.18	0.002	0.06
	+2w	2.9 (2.1;3.7)	3.4 (2.6;4.2)		0.37	0.37	.	.
	+3m	2.7 (1.9;3.6)	3.1 (2.2;4.0)	3.9 (2.9;4.8)	0.23	0.57	0.09	0.26
Vascularity	w1	6.6 (6.1;7.1)	5.4 (4.9;5.9)		0.001	0.001	.	.
	w2	6.8 (6.1;7.4)	5.2 (4.5;5.9)		0.001	0.001	.	.
	w3	6.6 (6.1;7.1)	4.8 (4.3;5.3)	5.4 (4.9;5.9)	<0.000	<0.000	0.001	0.11
	+2w	6.0 (5.5;6.5)	4.4 (3.9;4.9)		<0.000	<0.000	.	.
	+3m	4.7 (4.1;5.3)	4.5 (3.9;5.1)	3.4 (2.8;4.1)	0.017	0.70	0.008	0.022
Relief	w1	5.2 (4.8;5.7)	4.5 (4.0;5.0)		0.044	0.044	.	.
	w2	5.2 (4.6;5.8)	4.2 (3.5;4.8)		0.030	0.030	.	.
	w3	4.9 (4.3;5.4)	4.2 (3.7;4.7)	4.3 (3.7;4.9)	0.1973	0.0833	0.1837	0.7902
	+2w	3.8 (3.3;4.3)	3.6 (3.1;4.1)		0.5056	0.5056	.	.
	+3m	3.4 (2.9;3.9)	3.3 (2.8;3.8)	3.2 (2.6;3.7)	0.8350	0.8564	0.5583	0.6619
Global opinion	w1	5.9 (5.4;6.3)	5.2 (4.8;5.7)		0.041	0.041	.	.
	w2	6.0 (5.4;6.6)	4.8 (4.2;5.5)		0.015	0.015	.	.
	w3	5.6 (5.1;6.1)	4.9 (4.4;5.4)	5.1 (4.5;5.6)	0.11	0.041	0.15	0.62
	+2w	4.5 (4.0;5.0)	4.2 (3.7;4.7)		0.43	0.43	.	.
	+3m	3.9 (3.4;4.4)	3.9 (3.4;4.4)	3.7 (3.1;4.2)	0.82	0.95	0.60	0.56

Least squares means (with 95%CI) for scars with a mean baseline value and mean scar age.

Pairwise comparisons are not corrected for multiple testing.

Abbreviations: PHT: Patients of Passive Hydrotherapy; AHT: Patients of Active Hydrotherapy; UCT: Patients with Usual Care Therapy

Note: estimate of redness (a* value) at 3-week PHT is based on 7 (instead of 33) scar sites.

Scar related parameters

- REDNESS (a*) (Figure 3)

In all groups, there was a significant change in redness over time (p<.0001 for the PHT and UCT, p=.0086 for the AHT). The redness declined, although there was a temporary increase during the 3-week intervention in the PHT. The differences in evolution of a*value between the PHT and AHT, between PHT and UCT, and between AHT and UCT were significant (p<.0001, p<.0001 and p=.0141, respectively). Pairwise comparisons (Table 4) showed significant lower results in AHT compared to PHT after three weeks of intervention (p<.0001) and at follow-up after 2 weeks (p=.0194), this after correction for baseline value, gender and scar age. Additionally pairwise comparisons showed significantly lower results in UCT group compared to the PHT group after 3 weeks of intervention (p=.0024) and at follow-up after 3 months (p=.0039), after correction for baseline values and scar age.

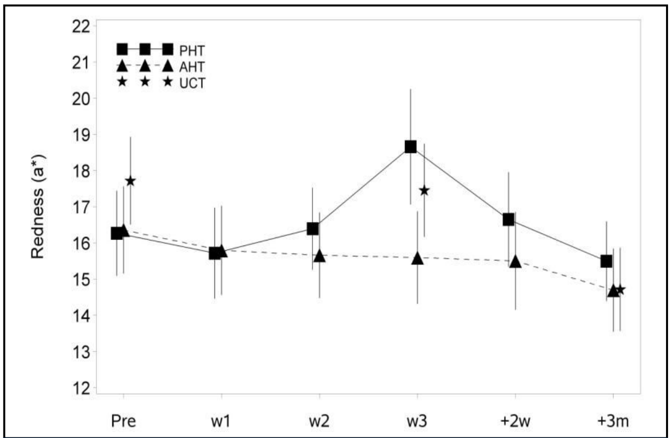

Figure 3: Evolution of redness (a*). Note: estimate of a* value at 3-week PHT is based on 7 (instead of 33) scar sites.

Abbreviations: PHT: Patients of Passive Hydrotherapy; AHT: Patients of Active Hydrotherapy; UCT: Patients with Usual Care Therapy

- TRANSEPIDERMAL WATER LOSS (TEWL) (Figure 4)

There was a significant evolution of TEWL in UCT (p=.0052) and AHT (p=.0396). The difference in evolution of TEWL between PHT and AHT, and between PHT and UCT were significant (p=.0048 and p=.0001, respectively). In the UCT the TEWL values diminished especially during the first 3 weeks. After correction for baseline value, gender and scar age at each time point, the pairwise comparisons indicated a significant lower TEWL at 3-month follow-up in AHT (p=.0172) compared to PHT (Table 4).

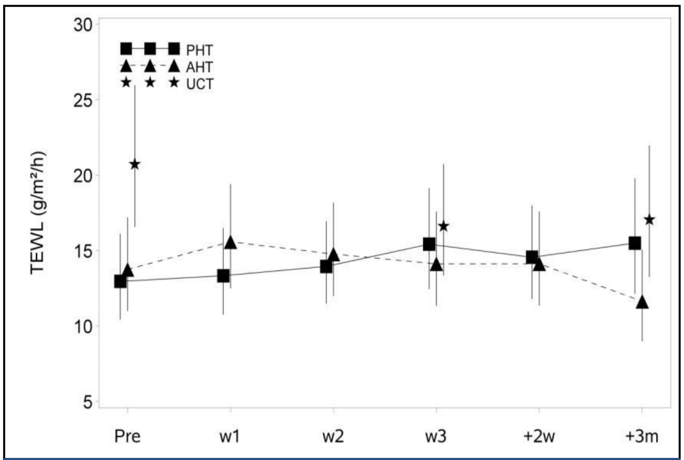

Figure 4: Evolution of TEWL.

Abbreviations: PHT: Patients of Passive Hydrotherapy; AHT: Patients of Active Hydrotherapy; UCT: Patients with Usual Care Therapy

- POSAS PATIENT SCALE ITCH (Figure 5)

The evolution of itching showed significant p-values in PHT (p<.0001) and AHT (p=.0089). The decrease of itching was significantly different between PHT and UCT (p<.0001), and between AHT and UCT (p=.0313). After correction for baseline value, gender and scar age pairwise comparisons showed significant lower itching score after one week in PHT compared to AHT (p=.0142) and after 3 weeks compared to UCT (p=.0017) (Table 4).

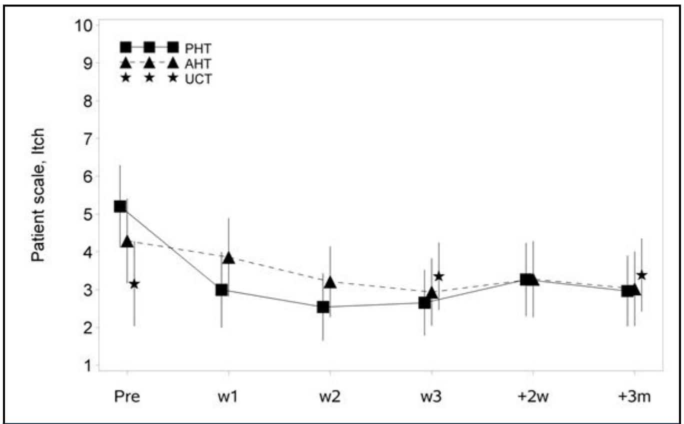

Figure 5: Evolution of itching.

Abbreviations: PHT: Patients of Passive Hydrotherapy; AHT: Patients of Active Hydrotherapy; UCT: Patients with Usual Care Therapy

- POSAS OBSERVER SCALE VASCULARITY (Figure 6)

There was a significant change over time (p<.0001) in all three groups. The item vascularity of the POSAS scale declined over time, although there was a temporary increase of vascularity score during the 3-week intervention in the PHT group. The differences in evolution of vascularity score between the PHT and AHT, and between AHT and UCT were significant (p<.0001, p=.0004, respectively). Pairwise comparisons (Table 4) showed significantly better results in AHT (except at follow-up after 3 months) compared to PHT (p<.0012), in UCT (after 3 weeks and at follow-up after 3 months) compared to PHT (p<.0076) and in UCT compared to AHT at follow-up after 3 months (p=.0225), this after correction for baseline value, gender and scar age.

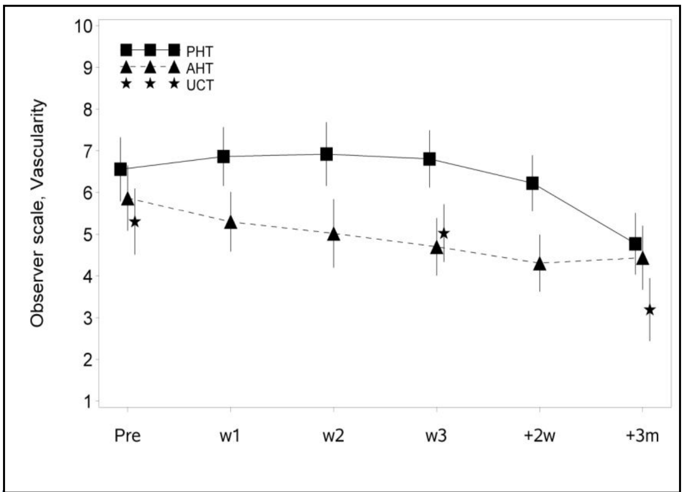

Figure 6: Evolution of vascularity (POSAS – observer scale).

Abbreviations: PHT: Patients of Passive Hydrotherapy; AHT: Patients of Active Hydrotherapy; UCT: Patients with Usual Care Therapy

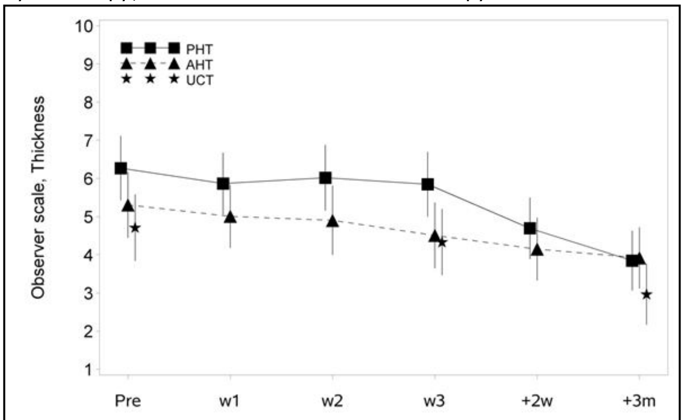

Figure 7: Evolution of thickness (POSAS – observer scale).

Abbreviations: PHT: Patients of Passive Hydrotherapy; AHT: Patients of Active Hydrotherapy; UCT: Patients with Usual Care Therapy

- POSAS OBSERVER SCALE THICKNESS (Figure 7)

In all three groups, the item thickness of the POSAS scale decreased significantly over time (p<.0001). The difference in evolution of thickness was only significant between PHT and AHT particularly due to the change during follow up. (PHT stronger decline than AHT) (p<.0027). The comparisons of post-baseline thickness between groups were not significant.

- POSAS OBSERVER SCALE RELIEF (Figure 8)

The evolution of the item relief of POSAS scale declined over time in all groups (p<.0001 for PHT and AHT, p=.0003 for UCT). The difference in evolution was only significant between PHT and UCT (p<.0038). Pairwise comparisons (Table 4) showed only significantly less relief in AHT after one week (p=.0444) and after two weeks of aquatic exercise (p=.0301), after correction for baseline value, gender and scar age.

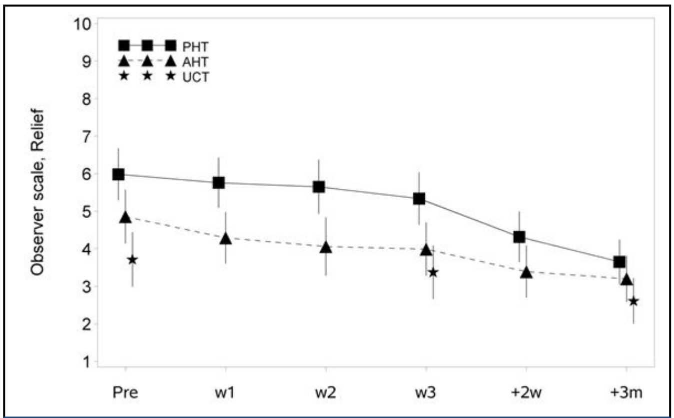

Figure 8: Evolution of relief (POSAS – observer scale).

Abbreviations: PHT: Patients of Passive Hydrotherapy; AHT: Patients of Active Hydrotherapy; UCT: Patients with Usual Care Therapy

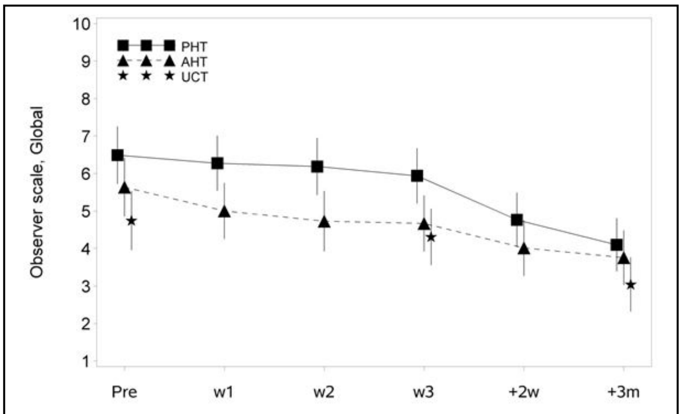

Figure 9: Evolution of global opinion (POSAS – observer scale).

Abbreviations: PHT: Patients of Passive Hydrotherapy; AHT: Patients of Active Hydrotherapy; UCT: Patients with Usual Care Therapy

- POSAS OBSERVER SCALE GLOBAL (Figure 9)

In all three groups, the global score of the POSAS scale improved significantly over time (p<.0001), although the difference in evolution was only significant between PHT and AHT (p=.0191). After correction for baseline value, gender and scar age, pairwise comparisons showed significantly better results in the AHT group after 1week (p=.0407), after 2 weeks (p=.0155) and after 3 weeks of aquatic training (p=.0407) compared to the PHT (Table 4).

DISCUSSION

This study is a pilot project and the first to investigate the short-term effects of diverse applications of hydrotherapy in adults after burns.

Most important results are:

1) A significant increase in hand grip strength in the AHT group. In the PHT hand grip strength decreased temporary during the 3-week intervention and returned to normal again at 3-month follow-up.

2) Significant improvements in redness and POSAS observer scale vascularity over time in all groups, with a temporary increase of redness/vascularity score during the 3-week intervention in the PHT group.

3) Significant lower itching score in the PHT group during the 3-week intervention.

In this study we examined both passive and active hydrotherapy, the former uses natural thermal mineral water (see additional file 1), the latter is performed in normal public pool chlorinated water (see additional file 2). The use of thermal mineral water for medical treatment is well-known, although there is relatively little supporting evidence. Some authors suggest that most mineral ingredients of thermal water would be absorbed through the skin [30,31]. In comparison with tap water no significant changes in renal response, in heamodilution or cardiovascular outcome were observed [30]. Although in addition to the natural thermal mineral water, PHT patients also received other modalities intended to have an enjoyable and relaxing effect (such as hydrojet massaging baths, underwater massages, etc.) and consequently showed an increase of general well-being (psychological effect) [31,32]. Some trials of PHT indicated significant improvements in pain and general well-being on patients with osteoarthritis of the knees, rheumatoid arthritis, chronic low back pain and fibromyalgia [31,32].

On the other hand, the working mechanism of AHT is based on buoyancy, immersion, water resistance, temperature and exercise aspects. The 12-week resistive aquatic program of Zoheiry et al. showed improvements in physical parameters of burned patients compared with an on-land exercise program [21]. According to the gate theory of Melzack and Wall, water immersion (might have) induced an increase of methionine-encephalin plasma levels and suppressed plasma β-endorphin, corticotrophin and prolactin levels [33,34]. Muscle relaxation, reduced joint swelling, and improvements in mood and tension may occur as a result [30,31,33–36]. In a review by Geytenbeek, various active trials resulted in significant improvements of pain in patients with osteoarthritis of the hip, rheumatoid arthritis, low back pain, ankylosing spondylitis and fibromyalgia [30,37]. Since both intervention groups in this study continued the usual care of burn scar treatment and moreover the effect of thermal mineral water treatment was low, we assumed in our study that the most important cause of differences in outcomes between both intervention groups (PHT and AHT) is the exercise and rehabilitation aspect.

An important outcome measure of patient satisfaction is therapy compliance. In the PHT group only one patient stopped the therapy after 2 weeks due to personal reasons. This treatment was organized for all participants at the same venue and time. Participants actually resided at the venue which was furthermore more than 800 km from home and therapists were continually present. The compliance of the UCT (continuation of physical therapy, pressure and silicone therapy) was not registered in detail. In the AHT group all 14 patients continued the 3-week intervention without drop-out. Participation in the AHT group required flexibility, commitment and organization, especially in combination with family, children, social life, work, physiotherapy, travel to swimming pool, etc. They lived at their own home and were responsible for their own travel to and from the intervention venue. Since participation to the AHT group required a great personal commitment, we believe that the aquatic exercise shows several advantages for patients with burn scars above the physical results. The aquatic exercise promotes a gradual and controlled public exposure of their scars and provides contact with peers. In this intervention the patients and therapists were alone in the pool with the exception of competitive swimmers training in one lane. Moreover, Reilly and Bird supported the effect of group therapy in a community swimming pool to be more effective than individual treatment in a hospital setting [38]. Peer support has a positive influence on social interaction, associated with better social reintegration [39]. In addition, the AHT received technical swimming instruction and not only physical training and swimming progress was systematically tracked with a 4 minute swimming test. This all combined might have provided some additional motivation.

The patient related characteristics pre-intervention were almost comparable in all three groups. Nevertheless, most scar related characteristics differed. Therefore the focus in the between-group analysis was on the post-baseline values in which the groups were compared after correction for the baseline value, sex and (scar) age. At baseline, the patient and observer score of POSAS were the highest in the PHT group, although objective scar evaluations were higher in the UCT group [34]. Regarding the physical parameters, no significant and no clinically relevant differences were shown in the three groups at baseline.

The ability to walk considerable distances without experiencing serious fatigue is an important functional ability for patients recovering from burns. Following a prospective study of Jarett et al. the functional exercise capacity in burn patients was still markedly reduced at 6 months after discharge, being approximately 50% of the predicted normal values [40].

In our study the 6-minute walk distance increased similarly within all three groups, although only significantly for the AHT and UCT. This coincides with the expected learning effect of approximately 10%. Most probably the 3-week AHT intervention was too short to obtain any clear functional improvements. Porter and co-authors suggest training programs of at least 6 weeks or even 12 weeks (depending on the TBSA burned) to obtain improvements in the rehabilitation after a severe burn injury [41].

With regard to the PHT intervention, the focus here was not on the physical aspect, therefore we would not expect an important improvement of the functional status. Moreover, the patients of this group had a higher BMI, which could refer to a more sedentary life style in general. Perhaps when using PHT there could be some benefit to add recreational physical training such as walking or cycling to the program to avoid the apparent stagnation in walking progress due to the passive nature of the treatment.

Implementation of e.g. Dynaport Activity Monitor [40] or a questionnaire such a SF-36 [43] or Squash questionnaire [44] in future training programs could also be appropriate to measure the recovery of physical and mental health.

Hand strength is an important indicator of activities in daily life [45]. Previous studies of Suman [14,15] and Cucuzzo [13] confirmed the effect of muscle strength due to exercise which can possibly be translated to a shortened rehabilitation period and successfully return to activities of daily living. In our study, despite the short intervention period of only 3 weeks, the AHT group had a significant improvement of hand strength compared to the PHT group, which is a relevant improvement of 1.5 kg.

A more complete evaluation of muscle strength of upper and lower limbs would be more appropriate. In future research projects, the strength test battery should be extended beyond the use of handheld dynamometer [46].

In examining the scar related parameters, we did not take into account the contralateral healthy control sites due to the seasonal and topographical variations and in outcome (e.g. more sun exposure in the PHT group and another climate in France). Therefore, we only presented the measurements of scars. Redness (a*) is considered one of the major features of hypertrophic scarring after burns [2]. Somewhat surprising is the increase of redness at the end of therapy in the PHT. The influence of treatment could possibly explain this temporary increase which could be due to water temperature (34°C) and intense scar mobilizations caused by hydrojet massages and filiform showers during PHT. After the intervention, a* values diminished again, which indicated a reduction of redness. However, note that due to technical problems with the Chromameter CR-300 after 3-week PHT, the estimate for the average a* value at that specific time point was based on only 7 (instead of 33) scars. In the AHT and UCT a clinically important decrease of a* values over time was found.

In all groups usual care therapy was continued. Based on the available literature, silicone and pressure therapy, which are part of the usual therapy, are the most frequently utilized and proven methods to improve thickness, pliability and erythema [2,3,5,47–55]. The daily load of PHT (3 to 4 hours a day) during 3 weeks implied that these patients were not able to wear pressure garments and/or silicone sheets during the 4-hours PHT treatment. This could have a relevant influence on redness in the PHT group. The AHT and UCT patients wore pressure and/or silicone therapy during the majority of the day, although, this was not registered in detail. It was no surprise that these findings are in line with the results of the POSAS observer scale vascularity.

Another important scar related parameter is TEWL, which is a physiological parameter and indicates the efficiency of the skin barrier function [26]. According to Suetake and co-workers high TEWL values were reported initially after reepithelialisation with a gradually decline thereafter [56]. A normalisation of TEWL took place between 6.5 and 13 months. These findings were in agreement with the report of Anthonissen and co-workers [26]. In the latter study the scar age was relatively low, indicating that time after burn varied between 4 weeks and 36 weeks and a significant negative relation was shown between mean TEWL and time after burn. This is in accordance with the gradual decline after initial high TEWL values of Suetake and co-authors [56]. Although in our study the mean scar age is relatively high. In the PHT, AHT and the UCT group, the scar age is respectively 5.54 months, 5.96 months and 4.96 months. There was little evolution in TEWL, which is in line with the normalisation after 6.5 months [56]. The sudden decline of TEWL in the AHT group at 3-month post-intervention is not clear. Moreover, we have to consider the SEM of the TEWL values, which are rather high, up to 2.76 $g/m^2/h$ (1.83-3.73) [26]. This exceeds the mean difference of TEWL values between 2-weeks post-intervention and 3-months post-intervention in the AHT group.

Quality of life is also an important factor in patients with non-life threatening but painful and disabling condition such as burn scars. Itching after burns can be very annoying and it is an important aspect of quality of life. Both intervention groups showed a decrease in itching-score during the PHT and AHT intervention. The decrease during the first week of PHT was especially noteworthy, but there was no (significant) long term reduction in itching after the PHT intervention. Nevertheless, in a randomized controlled trial by Carpentier et al. in patients with chronic venous insufficiency, balneotherapy produced improvements in quality of life for at least one year [18]. Muster et al. demonstrated the beneficial effects of spa treatment on the quality of life in patients with rheumatoid arthritis [17]. There are some studies dealing with the influence of massage therapy and hydration on pruritus or itching in a burn population. According to some authors massage therapy and/or hydration could have a positive influence on itching [9,10], although others did not support these findings [8,11]. In our study there is an important reduction of itching during PHT, but no long term effect. Nevertheless, we believe that itching is an important indication to refer patients to a balneotherapy centre.

In addition to redness, thickness is another important feature of the scarring process and these develop parallel [2]. In our study the POSAS thickness scores diminished significantly over time in all groups. These findings are in line with other published studies. According to Nicoletis and Nedelec, hypertrophic scars significantly decreased in thickness over the time spans 3 to 6 months, 6 to 12 months and 3 to 12 months [57,58]. Following Nedelec and co-authors, the average total reduction of thickness of hypertrophic scars between 3 and 12 months is 1.38 mm, although not returning to normal skin thickness at 12 months after burn. Pressure therapy aims to improve scar thickness [2,49], although in our study all patients continued the usual care therapy (included pressure therapy), depending on the group allocation in combination with hydrotherapy. Therefore, we found that thickness remained stable during the PHT intervention, in agreement with the evolution of redness. This is probably due to the daily load of PHT, the intense scar mobilizations and the lack of pressure and silicone therapy during several hours a day. After the 3-week intervention of PHT, scar thickness clearly diminished again.

The item relief of the POSAS observer scale significantly improved over time in all three groups. This might not be surprising, besides the use of silicone gels [54], no other topical media resulted in an evolution of relief in burn scars. Furthermore this item has not often been studied.

The global opinion of an observer is mostly based on physical characteristics of burn scars such as redness, thickness and pliability. Two of these characteristics showed a significant improvement over time in all groups. These improvements are in line with the other scar related parameters. In accordance with previous results, neither PHT nor AHT seemed to have any additional beneficial effect in this parameter.

LIMITATIONS

There are some important limitations to our study:

1) An intervention period of three weeks is relatively short, especially for effecting physical parameters such as pulmonary function, hand grip strength and functional status. Based on the literature we would recommend an active program up to 8 to 12 weeks. A balneotherapy treatment in France usually lasts 3-weeks. This was the determining factor in intervention duration in all groups.

2) The follow-up period was rather short, only 3 months after intervention. In future research we would recommend a follow-up period up to 1 year. In our study we only observed the short term effects of hydrotherapy and it would be more interesting to examine long term effects especially when the intervention itself is longer.

3) Recruitment of burn patients is not straightforward, but we managed to include 42 patients from different burn centers. Nevertheless, this was time consuming, even with only 14 patients in each group. An a priori power analysis should be incorporated into future research. This pilot study can provide essential data to calculate power.

4) There was most likely a selection bias of patients included in the study. There could be a difference in motivation of patients of the PHT and AHT. Patients who participated in the PHT could enjoy a 3-week stay in France. On the other hand patients of the AHT were willing to start swimming (learn or relearn a new skill). Patients who were unable to participate in either intervention group, were included in usual care group.

5) Multiple observers were involved in this study; therefore, it could create some bias. Observers, however, were instructed to follow strict protocols in the assessment of physical parameters. The inter-observer reliability of the Minolta Chromameter CR300®, DermaLab® and POSAS questionnaire were good to excellent [25–27].

6) Psychosocial effects of short term hydrotherapy were measured during this study, although not reported in this paper. Maertens et al. [32] found a positive impact of the therapy on general health status and a reduction of pain and depressive feelings in burn-injured patients after short term PHT.

CONCLUSIONS

To the best of our knowledge this was the first study that investigated the short term effects of hydrotherapy in burn patients. AHT patients were willing to participate in an aquatic exercise training program, although only limited changes were observed because of the short intervention length. In addition to the temporary increase of scar redness during the intervention, PHT patients showed some reduction in short term itching problems. We can conclude that the small changes observed in some physical and scar related parameters are promising and more research in this field is indicated. Both types of hydrotherapy, especially AHT, are feasible and some measures can be eliminated in further research. There are no clear guidelines in the rehabilitation of patients with burn scars such as in patients with COPD and cardiac diseases. Since this explorative study showed no negative effects, we believe that hydrotherapy can offer added value to the accepted usual care therapy and rehabilitation programs of burn patients including pressure and silicone therapy but cannot replace these.

THERAPEUTICALLY RECOMMENDATIONS

Selection of therapy needs to be done based on a patient's specific problems and condition. So far, pressure and silicone therapy are the only evidence supported treatments in burn scar after care. Any other supplementary treatment of physical activity and topical care (balneotherapy, aquatic exercise, massage therapy and mobilisations) needs to be fine-tuned to individual patient complaints.

DECLARATIONS

Ethics approval and consent to participate

The study was approved by the Ethical Committee of the University Hospitals of Leuven (Belgium) (identification details of the ethics committee (OG032); chairman Prof. Minne Casteels, M.D.; protocol number ML4626; date of approval May 7th, 2008). A signed informed consent was obtained from all patients.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available due to individual privacy of patients but are available from the corresponding authors on reasonable request.

Competing interests

The authors declare that thay have no competing interests.

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Authors' contributions

All authors have made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data. They have been involved in drafting the manuscript or revising it critically for important intellectual content and have given final approval of the version to be published. Each author participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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ADDITIONAL FILES

Additional file 1		
Characteristics of intervention of passive hydrotherapy (PHT)		
2 types of treatments for burn injuries	**objective**	**positioning of patients**
1) basic treatment		
- standard baths	emollient, anti-inflammatory and relaxing function	sitting with trunk 45° flexed; immersed in water up to neck level
- air bubble baths	emollient, anti-inflammatory and relaxing function	sitting with trunk 45° flexed; immersed in water up to neck level
- hydrojet-massaging baths	emollient, anti-inflammatory and relaxing function	sitting with trunk 45° flexed; immersed in water up to neck level
- showers	anti-pruriginous function	standing
- sprays	anti-pruriginous function	standing
2) complementary treatment		
- underwater massage	softening, relaxing and scar mobilization effect	prone/supine position
- localized pulverizations of face and hands	anti-inflammatory and anti-pruriginous action	sitting
- filiform showers (adjustable pressure)	scar softening and itch soothing effect	standing
- thermal water spring water compresses	anti-pruriginous and anti-inflammatory effect	sitting
additional instructions		
- to drink daily at least 1.5 litre of thermal spring water		
- education about skin properties, hydration and make up	improve understanding of importance of hydration and motivation	
Characteristics of thermal water of Avène		
water temperature = 34°C		
mineral content < 300 mg/ml		
pH = 7.5		
$[Mg^{2+}]$ = 21.1 mg/l		
$[Ca^{2+}]$ = 42.7 mg/l		

Additional file 2	
Characteristics of intervention of active hydrotherapy (AHT)	
intake	**objective**
interview with aquatic expert before start of intervention	to determine individual objectives
aquatic exercise program	
1) light aerobic warm-up (10 minutes)	to enhance social contact and reduce anxiety
- walking forward, sideways and backwards in chest-level water	
- floating on the back	
- breathing exercises e.g. blowing bubbles under water	
2) aerobic capacity and strength training (40 minutes)	to individually determine and gradually adapt intensity of training over the training period
	to improve physical fitness/swimming technique
	to enjoy and to experience progress
- swimming (crawl, breaststroke) (low resistance)	
- aqua jogging (with a belt) (high resistance)	
- underwater cycling (low and high resistance)	
3) cool-down (10 minutes)	to enhance social contact enhance recovery
- walking in chest-level water	
- relaxation in supine position with a floating belt	
Characteristics of water of swimming pool	
water temperature = 27°C - 28°C	
pH value = 7,3	