Manual Therapy 14 (2009) 685–689

Contents lists available at ScienceDirect

Manual Therapy

journal homepage: www.elsevier.com/math

Original Article

# Stature recovery after sitting on land and in water

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ARTICLE INFO

*Article history:*
Received 10 September 2008
Received in revised form
14 March 2009
Accepted 28 March 2009

*Keywords:*
Spine
Intervertebral discs
Spinal shrinkage
Aquatic therapy

ABSTRACT

Back pain treatment in water has been commonly used although there is little evidence about its effects. One purported advantage for exercise is the reduced loading due to the buoyant force. The purpose of this study was to compare stature change, as a marker of spinal loading, after sitting in aquatic and dry land environments. Fourteen asymptomatic volunteers had their stature measured in a precision stadiometer, before and after a bout of physical activity and during a recovery period either sitting in water (head out of water immersion; HOWI) and sitting in a chair on land (SITT). Stature loss following exercise was as expected similar in both groups (SITT $= 89.2 \pm 5.4\%$ and HOWI $= 86.5 \pm 8.1\%$; $p = 0.33$). When stature recovery was compared between the water and land environments, HOWI ($102.2 \pm 8.7\%$) showed greater recovery than SITT ($86.5 \pm 6.3\%$) after 30 min ($p < 0.05$). These results suggest that HOWI facilitated more rapid stature recovery through lower spinal loading and supports use of this technique to reduce spinal loading during recovery.



## 1. Introduction

Low back pain is both very common and of high impact in society. The World Health Organization (WHO) report that more than 80% of the global population are affected by back pain at some point in life, the impact of which is seen in personal suffering, lost productivity and health care cost. (Svensson and Andersson, 1989; Graf et al., 1995; Wilke et al., 1999; Norcross et al., 2003). Treatment costs are high and represent a burden for the patients and/or State (Svensson and Andersson, 1989; Deyo et al., 1991; Wilke et al., 1999).

Compressive loading of the spine is a key factor in determining the risk of developing back pain and guidelines recommend seeking methods to minimize such loads (van Deursen et al., 2005). Long periods of compressive loading are associated with a progressive loss of fluid from the intervertebral discs and associated increases in loads of other spinal structures e.g. facet joints (Althoff et al., 1992; Graf et al., 1995; Leivsth and Drerup, 1997; Lengsfeld et al., 2000). Measurement of the rate and extent of disc height has been advocated as an effective marker of spinal loading (Althoff et al., 1992; Rodacki et al., 2003).

A number of studies have indicated that low back pain is closely related to the inability to recover stature following a period of loading (Rodacki et al., 2003; Healey et al., 2005b). Several studies have investigated different recovery strategies aimed at promoting stature recovery, for instance, Rodacki et al. (2003) and Healey et al. (2005b, 2008) analyzed the effects of the side lying, whereas others have analyzed the partial gravitational inversion (Healey et al., 2005a) and the sitting position (Althoff et al., 1992; Beynon and Reilly, 2001; van Deursen et al., 2005). In a recent work, Healey et al. (2005a) showed that postures in which spinal loading is reduced either by altering gravitational loading or muscle activity are more effective for the restoration of intervertebral space.

A frequent treatment applied to reduce the loading on the spine and to treat back pain and spinal pathologies is aquatic therapy. Such treatment is predicated on the assumption that the buoyant force will reduce the spinal loading and thus offer relief from back pain (Konlian, 1999; Israel and Pardo, 2000; Masumoto et al., 2004). Several studies (Guillemin et al., 1994; Ariyoshi et al., 1999) have reported pain reduction after performing aquatic therapy. Others (Konlian, 1999) have indicated that aquatic therapy reduces the risk of further insult to the damaged tissues. However, studies quantifying the behavior of the spinal column in response to aquatic therapy are scarce in literature. Thus, the present study aimed to

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doi:10.1016/j.math.2009.03.007

**Table 1**
Average physical characteristics (±SD) for the participants.

| Gender | Age (years) | Weight (kg) | Stature (cm) | BMI (Kg/m$^2$) |
|---|---|---|---|---|
| Female | 22.5 ± 2.9 | 59.7 ± 5.4 | 168.1 ± 0.04 | 21.1 ± 1.3 |
| Male | 21.2 ± 2.4 | 67.8 ± 6.9 | 174.2 ± 0.05 | 22.3 ± 2.6 |

compare stature recovery in aquatic (head out of water immersion; HOWI) and dry land (SITT) environments.

## 2. Methods

### 2.1. Participants

Fourteen healthy, asymptomatic individuals (7 men and 7 women), with no history of back pain in the 6 months prior the study, volunteered to participate. Participants were able to swim (familiarized with the water) and had a body mass index smaller than 25 kg/m$^2$. Table 1 shows the physical characteristics of all participants. The study was approved by the Ethics Committee of the Pontifical Catholic University of the State of Paraná and the participants signed a free and informed consent form.

### 2.2. Experimental procedures

Each participant attended the laboratory on two different occasions, each in the morning and within the first three hours after waking. Changes in stature were assessed in two conditions: sitting immersed in water (HOWI) and sitting on dry land (SITT). The order of the conditions was randomly assigned in an attempt to reduce any order effects. A minimum period of 24 was imposed between experimental sessions.

The assessment protocol included: familiarization of the participants with the measuring equipment (precision stadiometer) (Fig. 1); resting in the Fowler's position; loading done with the use of a backpack and stature-recovery period in the sitting position, on the land and in the water.

The purpose of the training and familiarization with the stadiometer procedures was to improve the repeatability of measurement and the participants were considered as trained when the standard deviation was less than 0.5 mm for 10 consecutive measurements of the stature (Eklund and Corlett, 1984; Rodacki et al., 2001, 2003; Dezan et al., 2003; Fowler et al., 2005). Thus, measurements were deemed to provide reliable data after this short period of training (5–8 min).

After the familiarization period, participants rested for 30 min in a supine position, with their hip and knees flexed and ankles supported on a comfortable surface (Fowler's position). Such a position has been proven effective to recover the vertebral column's length and to eliminate the interference prior loading to the spine (Dezan et al., 2003; Rodacki et al., 2003, 2005). After the resting period, participants stood up for 90s before the first measurement of the individuals' stature was carried out and named PRE.

Participants were then asked to carry a dorsal backpack, whose weight corresponded to 10% of the body weight, for 20 min, in order to induce a compressive spinal load and induce the loss of stature. After the 20-min period, a second measurement was taken and named LOS.

Following loading the participants undertook one of the two stature-recovery strategies, which involved sitting for 30 min in a chair without a backrest, with their feet on the ground either on dry land (SITT) or immersed in water (HOWI) up-to the level of the seventh cervical vertebra (C7) (Fig. 2). Small postural adjustments were allowed. The water temperature was kept at 33.1 °C ± 0.6.

During the recovery period (HOWI, SITT) dry land measurements of stature variations were taken with the stadiometer every 10 min and called HOWI10, HOWI20, HOWI30 and SITT10, SITT20 and SITT30. Before each measurement, the participants stood up for 90 s in order to reduce the effect of soft tissue creep deformation of the lower limbs (Foreman and Linge, 1989).

### 2.3. Stature-changing measurements

Changes in stature were quantified using a precision stadiometer as proposed by Eklund and Corlett (1984) and modified by Rodacki et al. (2001). The stadiometer consisted of a rigid metal frame, tilted backwards, 15° in relation to the vertical plane. Five horizontal beams (postural controls) were adjusted at specific anatomic points (Fig. 1): the largest head protuberance (occipital); the deepest point of the cervical lordosis curve (approximately at

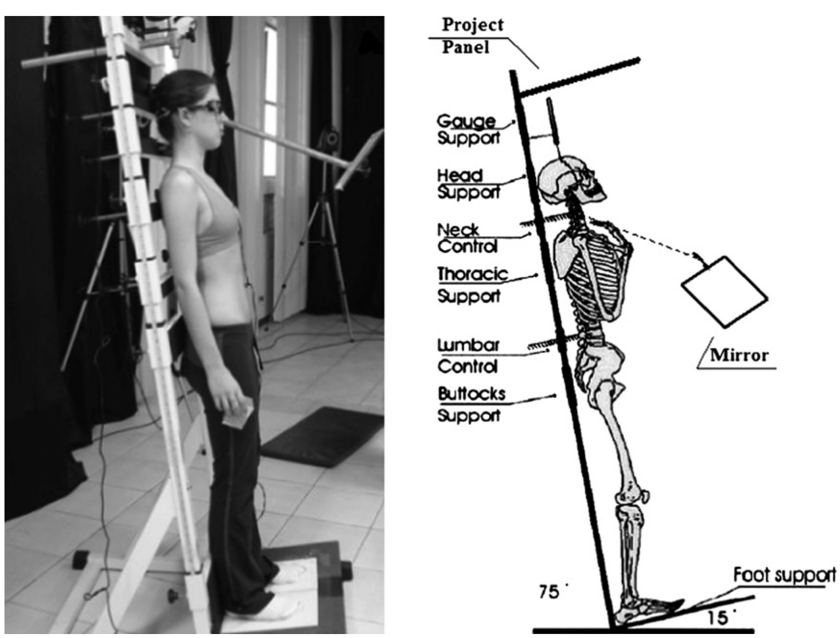


**Fig. 1.** Precision stadiometer (adapted from Rodacki et al., 2001).

**Fig. 2.** Sitting position inside the water.

C4); the most prominent point of thoracic kyphosis (approximately at T7); the deepest point of lumbar lordosis curve (approximately at L3) and the apex of the buttocks (approximately at the middle ridge of the sacrum). At the lumbar and cervical curves, a screw (perpendicular to the postural control) was designed to move forwards to touch the deepest point of the concavity (Rodacki et al., 2001).

For the measurements, the participants were instructed to stand up, knees straight and to place their feet comfortably with weight evenly distributed and to lean back against the postural controls. The arms were left hanging, on the side of their thighs. Undesirable head movements were controlled by a pair of glasses with two removable laser-emitting devices (class 2, wave-length 630–680 mm and maximum output $< 1$ mW), battery-operated and assembled on the frame's side. An elastic band helped to keep the participant's spectacles in a comfortable and appropriate position, with relatively constant pressure. Horizontal and vertical alignment of the head was achieved by keeping the laser beams (left and right) at the center of two marks (diameter: 20 mm) that were fitted on two small magnets placed on the metallic surface of the projection screen, that is, a metallic frame place above the participant's head. A mirror ($200 \times 200$ mm) was placed $\sim 300$ mm in front of the participants in such a way that they were able to see and thus control the position of the laser beams. The magnets were positioned with the participant's head and neck in a normal and comfortable position.

A high-resolution ($\pm 0.005$ mm) Linear Variable Displacement Transducer (LVDT) was used to determine stature changes. The LVDT was placed on a rigid but adjustable frame, at the top of the stadiometer, in the middle of the horizontal beam and was positioned to coincide with the line of the longitudinal axis of the spine. Such settings permitted the distal end of the LVDT to rest directly on the highest apex of the head (vertex).

### 2.4. Statistical approach

The analysis of stature loss/recovery was carried out similarly to the approach described by Rodacki et al. (2003). The percentage of stature loss was determined by the equation (1):

$$\text{Stature Loss}(\%) = \frac{\text{LOS}}{\text{PRE}} \times 100 \quad (1)$$

The percentage of stature recovery was calculated by the equations (2) and (3), for HOWI and SITT respectively, in each measurement (10, 20 and 30 min of recovery):

$$\text{Stature Recovery}(\%) = \frac{\text{LOS}}{\text{HOWI}} \times 100 \quad (2)$$

$$\text{Stature Recovery}(\%) = \frac{\text{LOS}}{\text{SITT}} \times 100 \quad (3)$$

Stature changes (loss and recovery) were compared by a Two Way ANOVA for repeated measures. In order to establish the differences in terms of height changes, the Scheffé test was applied. Values of $p < 0.05$ have indicated statistical significance, and 95% confidence intervals calculated. The *Statistica Software, version* 7.0, was used for the statistical analyses.

## 3. Results

The repeatability of the measurements reported in this study for both experimental groups was consistent with that reported by several previous authors (Rodacki et al., 2003, 2005; Healey et al., 2005a,b). The mean error of assessments was deemed as acceptable for the purpose of this study ($0.42 \pm 0.13$ mm) with the mean SD below the values (0.5 mm) reported in other studies.

Loss in stature after the physical activity (carrying of a backpack) was $89.24 \pm 5.45\%$ for SITT and $86.58 \pm 8.17$ for HOWI. The stature losses were similar regardless the assessment days ($p = 0.33$).

Stature was seen to recover in the sitting position in both HOWI and SITT at all measurement points (Table 2).

Comparing HOWI and SITT, stature recovery was significantly greater ($p = 0.01$) at all three recovery moments for the water immersed condition. However, no significant differences were seen ($p = 0.38$) between the recovery moments on SITT (SITT10, SITT20, SITT30). In HOWI, significant stature difference was only seen at moment HOWI30 comparing to HOWI20 ($p = 0.03$), when a full stature recovery was observed ($102.23 \pm 8.76\%$). Fig. 3 shows the stature recovery at HOWI and SITT.

## 4. Discussion

Findings in this study show that the sitting position used during recovery did allow participants to recover the majority of their stature in both land or water environments. However, recovery following sitting whilst immersed in water was greater than that observed in normal (on land) sitting. An analysis of the stature loss, induced by the loading task, confirms that there was a similar loading imposed in each condition. It is therefore possible to compare the recover rates as the discs would be returning from a similar state of compression. It is also worth to note that the

**Table 2**
Percentage of stature recovery (±SD) in HOWI and SITT at moments 10, 20 and 30 min.

| | 10 min | 20 min | 30 min |
|---|---|---|---|
| SITT (%) | $88.06 \pm 5.71$ (84.76 – 91.36) | $86.59 \pm 5.10$ (83.64 – 89.54) | $86.58 \pm 6.39$ (82.89 – 90.28) |
| HOWI (%) | $96.23 \pm 8.78$ (91.16 – 101.31) | $95.03 \pm 7.92$ (90.45 – 99.60) | $102.23 \pm 8.76$ (97.17 – 107.29) |

Note: Values between brackets refer to the lower and upper confidence intervals, respectively.

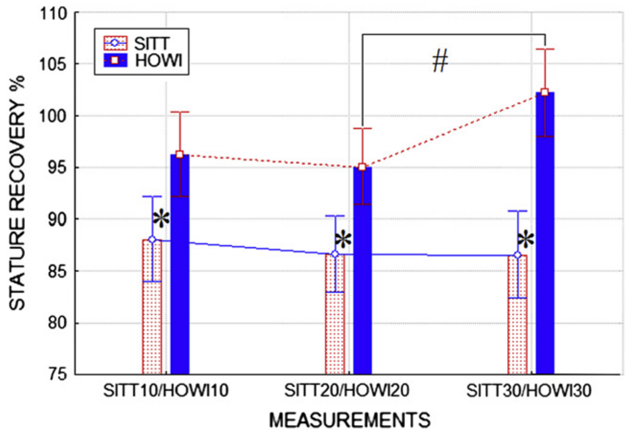


**Fig. 3.** Average percentage for stature recovery in HOWI and SITT at moments 10, 20 and 30 min. The symbol * indicates differences ($p < 0.05$) between experimental conditions (SITT and HOWI), while # refers to differences ($p < 0.05$) between recovery moments.

degree of stature loss is comparable with that induced in other studies (Rodacki et al., 2003; Healey et al., 2005a,b, 2008).

Whilst the induced shrinkage in stature was comparable with previous studies, the magnitude of the recovery in SITT ($86.58 \pm 6.39\%$) was smaller than that reported for studies where participants recovered using recumbent postures (Eklund and Corlett, 1984; Beynon and Reilly, 2001; Dezan et al., 2003; van Deursen et al., 2005; Healey et al., 2005a). Thus, irrespective of the whether immersion is used, sitting does not seem to offer the same degree of 'unloading' and thus may not be the most suitable recovery posture. Where immersed seating is used longer recovery time is necessary to achieve a full recovery of stature loss which may have implications for the viability of this technique for clinical application.

The seated posture, in both water and on land is likely to have induced greater muscle activation to sustain this posture compared to recumbent postures used in other studies. Healey et al. (2008) have shown a close negative relationship between muscle activation and both the rate and extent of stature recovery post-exercise. Muscle activation changes may also have influenced differences between water (HOWI) and land (SITT) conditions.

The greater stature recovery observed in the immersed condition may be attributed to some physical properties of the water e.g. buoyancy and hydrostatic pressure. These properties will have reduced the apparent weight of the body and thus diminished the muscular demand to sustain the erect posture of the upper segments (Skinner and Thomson, 1985; Cole et al., 1996; Degani, 1998; Konlian, 1999; Pöyhönen et al., 1999; Masumoto et al., 2004). Further to this, it is likely that maintenance of the up-right sitting posture will have been facilitated by the viscous a hydro-static forces acting upon the body, this would also help reduce the muscle activation and so spinal loading.

As well as the buoyant and hydro-static forces there may also have been benefits associated with the thermal effects of immersion in warm water. It is well known that muscles are able to relax in a greater extend when thermal effects are present (Konlian, 1999; Hinman et al., 2007). Thus, reducing the muscle activation may have reduced the compressive loading and so permitted greater fluid influx to the nucleus pulposus and greater stature gains. Other studies including electromyography assessment are necessary to further explore these arguments.

Rodacki et al. (2003) and Healey et al. (2005b, 2008) proposed that full stature recovery is important to reverse the effects of spinal loading and intervertebral disc loading which are believed to be closely related to back pain. Thus, methods involving strategies that provide the most effective ability to recover stature are important. Thus, the relatively long time required to provide significant changes in stature is not an attractive aspect of HOWI in comparison to other strategies used to recover stature (e.g. series of abdominal exercises). When sitting postures were compared (HOWI and SITT) a clear advantage of using water was identified.

The results of the present study must be viewed with some caution when extrapolating to clinical populations. It is possible that responses in healthy participants may not replicate the same behavior as participants with ongoing back pain, although studies by Healey et al. (2005a,b) offer some support to the assertion that, at least for patients with mild back pain, similar patterns of stature loss and recovery can be expected. To identify the likely mechanisms for the beneficial effects of immersion, it remains necessary to assess electromyography to determine the degree that water effects are due to buoyant forces or reduced muscle activation. Other studies are still required to further examine these preliminary findings.

## 5. Conclusion

In this study it was possible to observe that stature recovery occurs in all sitting postures, however, water immersion (HOWI) showed better results when compared with normal (dry land) sitting (SITT). Full stature recovery occurred only after 30 min in water, which was earlier than in land. A combination of the buoyancy and hydro-static forces and reduced muscle activation were effective to reduce the magnitude of the internal loads. Although immersed sitting was better than sitting on dry land, the amount of recovery was lower than that observed for recumbent recovery postures.

### Conflict of interest statement

Authors have exclusive academic interest in this manuscript and there are no conflicts of interest in the present submission.

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