ORIGINAL ARTICLE

Effects of immersion on the breathing parameters of patients with Duchenne muscular dystrophy

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ABSTRACT

In many rehabilitation centers, Aquatic Physiotherapy is commonly used as an optional treatment for Duchenne Muscular dystrophy (DMD) patients. However, there is so little scientific evidence about the immersion effects on the breathing parameters of these patients. **Objective:** Our goal was to evaluate the immersion effects to the depth of the seventh cervical vertebra (C7), related to the breathing parameters in DMD patients. **Method:** Fifteen boys with DMD participated of the study, averaging 12 years in age. Clinical history and general information were investigated, and the following parameters were evaluated on the ground and inside the pool: Partial Oxygen Saturation (SpO_2), heart rate (HR), maximal inspiratory (PI Max.) and expiratory (PE Max.) pressures, minute volume (MV), respiratory rate (RR), tidal volume (TV), Forced Vital Capacity (FVC) and peak expiratory flow (PEF). The SpO_2 diminished after the aquatic evaluation when compared to values beforehand (p = 0.01). RR was higher inside the pool than outside (p = 0.02). PI Max. and PE Max. did not change inside the pool. **Results:** Analyzing the results for volumes, FVC and EPF were reduced inside the pool when compared to evaluation on solid ground (p = 0.004). MV and TV did not change. A positive correlation between ground and pool values of FVC and PEF was seen (FVC: r = 0.692, p = 0.006; EPF: r = 0.913, p = 0.0001). C7 immersion was able to reduce SpO_2, FVC, and PEF, while increasing the RR of DMD patients. **Conclusion:** With the correlation between ground and pool values of FVC and PEF encountered in this study, there is a possibility of predicting pool values for these parameters using only the ground data. These findings could lead to a scientific base for a better Aquatic Physiotherapy prescription for DMD patients, at different pathology stages.

Keywords: hydrotherapy, immersion, muscular dystrophy duchenne, pulmonary ventilation

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INTRODUCTION

Duchenne Muscular Dystrophy (DMD) is a disease characterized by progressive loss of muscle strength, contractions, atrophies, and deformities, resulting in a loss of gait, impairment of respiratory muscles, and death by respiratory failure. The incidence is approximately one in every 3,000 live births.[1,2] There has been an important advance in the respiratory care of these patients due to the high mortality rate regarding pulmonary alterations.[2]

The forced vital capacity (FVC) is an important respiratory parameter which can reflect the clinical state of the individual. In progressive neuromuscular diseases, around the age at which walking ability is lost, the VC also tends to decline.[3-12]

Aquatic physiotherapy seeks to optimize overall muscular function, including those muscles involved in respiration, and to facilitate active movements in the liquid medium. However, the pulmonary system is amply affected by the immersion.[13]

When healthy individuals are immersed up to their necks, the total breathing work, per flow volume in liters, increases by around 60%. Three quarters of this effort is attributed to the increase in elastic work (redistribution of blood from the periphery to the thorax) and the rest is due to dynamic work (moving air against an increased resistance and increased hydrostatic pressure in the thorax).[14-17] The combined effect of these factors alters the pulmonary function, increases the respiratory work, and changes the respiratory dynamic.[13]

Most of the available literature is oriented towards physiological and aerospace studies characterized by a paucity of evidence based on a clinical environment. Furthermore, the information is based on healthy individuals in order to describe the effects of immersion on the pulmonary system.[13,18,19]

OBJECTIVE

The object of this work was to evaluate the effects of immersion up to the seventh cervical vertebra on the breathing parameters of patients with DMD.

METHOD

This cross-sectional study was carried out at the Association to Assist Children with Disabilities (AACD) and the project was approved by the Ethics Committee at the same Institution under Opinion No. 030/2008. The implementation was in accord with Resolution No. 01/88 by the National Health Council.

The patients selected were regularly monitored at the AACD and diagnosed with Duchenne Muscular Dystrophy. They all fulfilled the inclusion criteria of the proposed protocol: DMD diagnosis clinically established and confirmed my muscle biopsy; trunk control on a stable surface; degree of collaboration compatible with doing a respiratory evaluation; the obtainment of their Free and Informed Consent Form (FIC) and the absence of any episodes of pneumonia in the month preceding the evaluation.

The evaluations were done in the hydrotherapy department of the institution at two distinct times, seven days apart, by the same trained examiner. In one session, the evaluation was done on the ground with the patient sitting on a platform (42 cm high, 2.0 meters long, and 1.4 meters wide). In the other session, the evaluation was done in liquid medium with the patient sitting on the platform (42 cm high, 1.21 meters long, and 84 cm wide) immersed to the level of the seventh cervical vertebra in a therapeutic pool (1 meter deep, 12 meters long, and 3.5 meters wide) at the temperature of 33.5°C. The sequence of evaluations was chosen randomly.

All those responsible for the participants were informed as to the objective of the study and, after signing the FIC, they answered a brief questionnaire. The following parameters were measured during the evaluations: Partial saturation of oxygen (SpO_2), Pulse rate (PR), Minute volume (MV), Respiration rate (RR), Tidal volume (TV), Forced vital capacity (FVC), Maximal inspiratory pressure (PImax), Maximal expiratory pressure (PEmax), and Peak expiratory flow (PEF). Three readings of each respiratory variable were taken, and the highest was adopted.

The SpO_2 and PR were measured using the Onix 9500 Nonin Fingertip Pulse Oximeter®. The volumes and capacities were measured by means of a Ferraris Wright MK® Respirometer.

For indirect verification of the muscular breathing force, the maximum static breathing pressures (PI Max and PE Max) were measured using a Gerar® class B manovacuometer, capable of measuring positive and negative pressures.

The peak expiratory flow was quantified using a Mini-Wright® peak flow meter.

The data for SpO_2, PR, RR, TV, MV, PImax., PEmax., FVC and PEF was evaluated by the Wilcoxon-parametric analysis. Spearman correlations and Linear Regression were used for analyzing the FVC and PEF to correlate the data collected on solid ground and in a liquid medium.

RESULTS

The patients averaged twelve years of age, the weight averaged 40.18 kg, and the height, 1.43 meters. Of the fifteen patients, nine were wheelchair users and had lost their walking ability an average of 3.38 years earlier; none of them used bi-level positive airway pressure.

Of the fifteen patients, only one did not do physiotherapy or aquatic physiotherapy. The others did physiotherapy, aquatic physiotherapy, swimming, or yoga.

Among the data collected by the oximeter, no difference was noted in the pulse rate between the ground and liquid medium (p = 0.951) and after the evaluation in the liquid medium (p = 0.518). In the oximetry data there was also no difference between the ground and liquid readings. However, the readings obtained after the evaluation in liquid were lower than those taken before the evaluation in this medium (p = 0.012) (Figure 1).

In the pressure data collected via the manovacuometer, there was no difference in the PImax (p = 0.240) or the PEmax (p = 0.946) inside and outside the liquid medium.

Concerning the volumetric data acquired from the respirometer, we can see that the MV is at the point of becoming statistically greater in the liquid medium than what was measured on dry ground (p = 0.058). The CV showed no difference measured in or out of the water (p = 0.391). In contrast, the RR was greater in the liquid medium than on dry ground (p = 0.029) (Figure 2).

The FVC shows less in liquid medium than on dry ground (p = 0.008), and when readings inside and outside the liquid medium were compared, a positive correlation was observed between them (r = 0.692; p = 0.006) (Figure 3).

The PEF readings appeared as statistically lower in the liquid medium than those on dry ground (p = 0.024), and they show a positive correlation (Figure 4).

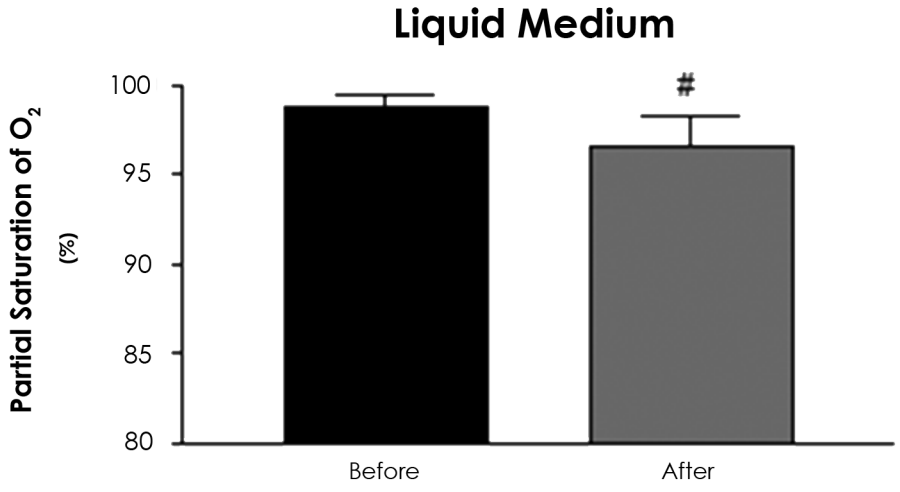

Figure 1. Data from partial saturation of oxygen collected in the liquid medium from DMD patients before and after evaluation. Before *vs*. After (Wilcoxon $p < 0.05$); N:15

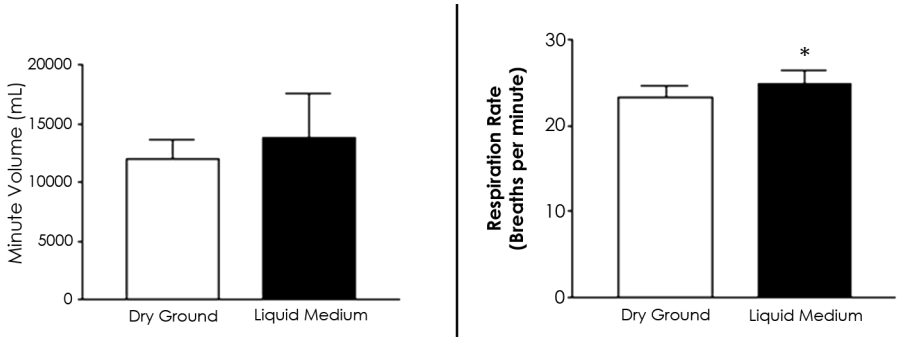

Figure 2. Data of MV (A), TV (B), and RR (C) from DMD patients on dry ground and in liquid medium. * Dry Ground *vs*. Liquid Medium (Wilcoxon, $p < 0.05$); N: 15

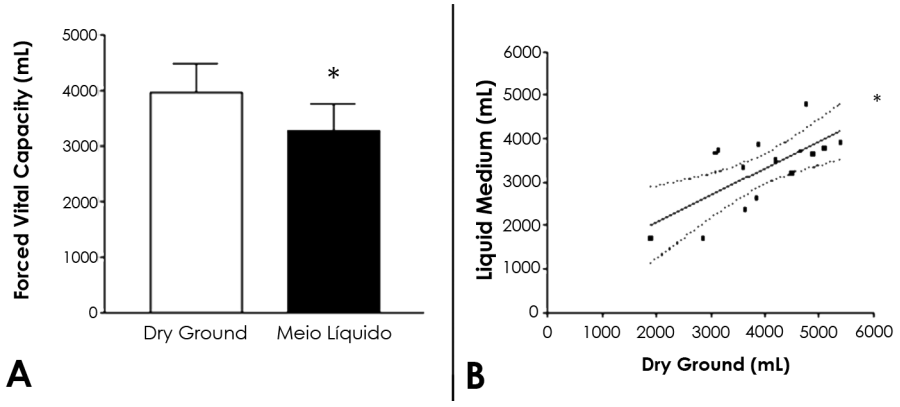

Figure 3. FVC data (A) and correlation of the FVC readings from DMD patients on dry ground and in liquid medium. * Dry Ground *vs*. Liquid Medium (A: Wilcoxon and B: Spearman, $p < 0.05$); N:15

DISCUSSION

According to the results from this study, the SpO_2 shows a statistically significant diminution after the liquid medium evaluation. This result is in concurrence with Cole & Becker,[13] when they reported that the diffusion capacity is slightly diminished when the individual is immersed up to the C7 level. Due to the lower lungs being less well ventilated and perfused with the movement of blood from the extremities to the upper thorax, the pulmonary vessels become engorged, diminishing the diffusion capacity and leading to a poorer exchange of gases.

Arborelius and associates report that during immersion the PR may remain unaltered or have a reduction reflex.[18] This corroborates the results of this present study in which no difference was observed in this variable when comparing between the media evaluated.

There were no changes between the readings for PImax and PEmax when analyzed on dry ground or in the liquid medium. These results suggest that the hydrostatic pressure exerted on the rib cage at the analyzed level of immersion was insufficient to impose a resistance to the respiratory musculature to the point of reducing the contraction capacity of these muscles. Hydrostatic pressure increases with the depth of immersion. Since the patients evaluated here were sitting immersed up to the C7 level, the hydrostatic pressure on the rib cage is less, approximately 20 cm of H_2O,[19] for this section is close to the surface of the water and is thus less influenced by it.

When an individual was immersed, the TV does not change, however, there was an increase in PR and consequently a significant increase in MV. Chouckroun et al.[17] evaluating healthy subjects at different temperatures, concluded that in thermoneutral water (34°C) the TV remains unchanged. Although the water temperature had no influence in TV changes, other variables are temperature dependent. According to Bach,[20] at the initial stage of pulmonary impairment the TV remains unchanged.

The RR increased when patients were immersed as a result of the reduced expandability of the rib cage and pulmonary compliance. Hence the individual needs to breathe more times per minute to fulfill his needs. Under these conditions there are circulatory, respiratory, and biomechanical alterations that lead to a pulmonary overload and a 60% increase in respiratory work, justifying these results.

As to the FVC, a 17% reduction was observed when the patients were immersed. In normal individuals the reduction is around 10%.[21-25] The literature emphasizes that during immersion around 700 ml of blood is relocated to the thorax-200 ml to the heart and 500 ml to the intrathoracic region.[18,21,22]

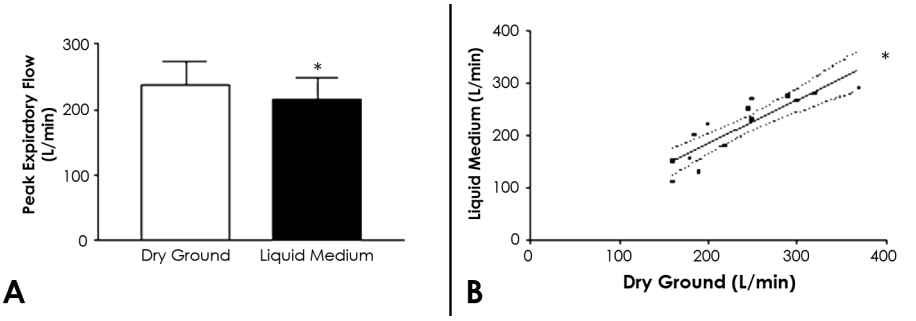

Figure 4. PEF data (A) and the correlation of PEF readings (B) from DMD patients on dry ground and in liquid medium. * Dry Ground *vs*. Liquid Medium (A: Wilcoxon and B: Spearman, $p < 0.05$); N:15

For those authors, the reduction in VC occurs with this increase in the intrathoracic volume of blood, leading to a diminution in pulmonary compliance.

The PEF diminished when the individual was immersed. According to Cole & Becker,[13] this diminution stems from the increased pressure on the rib cage, reducing its circumference and thereby increasing the airflow in the airways. Studies on the biophysiology of immersion[22] on healthy individuals also support this relationship.

According to the latest consensus concerning DMD, there is a lower limit to the FVC and PEF values to predict survival, in order for these patients to be recommended for coughing assistance methods.[2] The values cited in this text are: FVC < 1 L and PEF < 270 L/min. The results obtained in this study point to a reduction in these variables in liquid medium, and there are positive correlations between the readings on dry ground and in liquid medium. According to this information, we can suggest a pilot calculation to predict FVC and PEF readings in liquid medium based on dry ground readings. Aside from not having an impressive number of evaluated subjects, one can arrive at a correlation between FVC and PEF readings on dry ground and in liquid medium resulting in a straight line with little dispersion of data points. Therefore, according to this regression, one can arrive at the following equations:

$$CVF_{liq} = 0,6188*CVF_{solo} + 827,40$$
$$PFE_{liq} = 0,8354*PFE_{solo} + 16,84$$

The FVC_{liq} and FVC_{dry} represent FVC readings in liquid medium and on dry ground, respectively, and PEF_{liq} and PEF_{dry} represent PEF readings in liquid medium and on dry ground, respectively. Data similar to the present work was not found in the literature, however, it is believed that with a greater number of subjects included in this correlation it will be possible to predict the reduction in FVC and PEF in immersed DMD patients with greater precision.

CONCLUSIONS

During the immersion of patients with Duchenne muscular dystrophy up to the C7 vertebra it was possible to observe an increase in RR and a reduction in SpO_2, FVC, and PEF. Keeping in mind the respiratory impairments commonly found among these patients, such results highlight the importance of evaluating the breathing parameters before using Aquatic Physiotherapy in rehabilitation.

Considering the data that correlates the FVC and PEF readings on dry ground and in liquid medium, there is a way to estimate these breathing parameters in liquid medium based on data quantified on dry ground. Even though these values measured on dry ground are higher than those indicated by the Consensus and according to the estimates for liquid medium, they were below the predicted level and should be evaluated with greater caution before recommending aquatic physiotherapy.

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