Efficacy of 12-week Pulmonary Rehabilitation Program on Exercise Capacity of Burned Children: A Randomized Control Study

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Abstract

The purpose of this study was to evaluate the therapeutic efficacy of 12 weeks of pulmonary rehabilitation program with a treadmill on exercise capacity of burned children measured by maximum oxygen consumption (VO_{2max}). Methods: thirty children from both sexes with healed partial thickness thermal burns participated in this study one month after being discharged from hospital. The patients' age ranged from 7-17 years with total body surface area (TBSA) of 20-40 %. Patients were randomized to either group A (control) who received their traditional physical therapy program, or group B (pulmonary rehabilitation group) who received in addition to traditional physical therapy program a pulmonary rehabilitation program in the form of aerobic exercises on a treadmill. The treatment was continued for 12 weeks at the frequency of 3 times per week. VO_{2max} and treadmill time were measured before treatment and after 12 weeks after treatment. Results: there were significant differences between the groups. VO_{2max} and treadmill time improvements for groups A and B were 26.9%, 25.6% and 58.6%, 60.5% respectively. Conclusion: adding aerobic exercises to traditional rehabilitation program is more effective in improving exercise capacity of burned children rather than performing traditional rehabilitation program alone, which accelerates the return of the children to their schools and perform their daily living activities.

Key words: Burn; Aerobic exercise; Exercise capacity

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1. INTRODUCTION

Burns have a catastrophic impact in terms of loss of human life, suffering, disability, and financial loss (Edlich et al., 2010). Severe burns represent a major physical and psychological event in a child's life. Progress in the treatment of burns, such as fluid resuscitation, early burn wound excision, new antibiotics, and nutritional support has reduced burn mortality (Przkora et al., 2005). Burned children living beyond the acute phase of injury often have extensive physical functional limitations (Suman et al., 2002). In addition they suffer from a decrease in pulmonary function, marked prolonged skeletal muscle weakness and low physical and functional capacity (exercise capacity), which are major obstacles preventing the burn victim from returning to school and performing daily living activities (Suman et al., 2001; Dasu et al., 2004; Willis et al., 2011).

The majority of existing rehabilitation programs were designed focusing on short term outcomes. They emphasize relief of scar contractures and generally do not incorporate a quantifiable exercise prescribed to increase musculoskeletal strength and functional outcome (Cucuzzo, 2001). Such reduction in exercise capacity of burned patients indicates a need for rehabilitative interventions that improve physical function and performance (Suman et al., 2002).

Pulmonary rehabilitation is a multidisciplinary program for patients with respiratory disease. Potential benefits include reduced symptoms, improved exercise tolerance and quality of life. It varies widely in duration, frequency and structure as well as the nature of health care professionals involved (Rochester, 2000). The exercise session lasts from 20- 90 minutes and therapy duration ranges from 6 to 12 weeks with 2 or 3 sessions/week (Reina-Rosenbaum, 1997). Some programs routinely include upper extremity exercises such as pulley weights and arm ergometry, and exercise training to lower extremities such as floor or treadmill walking, bicycling ergometry or stair climbing, they may include also breathing retraining such as diaphragmatic breathing and pursed lip breathing (Rochester, 2000).

Aerobic exercises are considered an important component of pulmonary rehabilitation programs as they improve the patient’s functional status and if the intensity of training is
adequate, they result in a physiological training effect in patients with pulmonary dysfunctions (Larson et al., 1999; Cheng et al., 2003). Aerobic exercise is any activity that uses large muscle groups which overloads the heart and the lungs and causes them to work harder than at rest for a period of 15 to 20 minutes or longer while maintaining during 60-80% of this period maximum heart rate (Panton et al., 2004). Randomized controlled trials have demonstrated consistently that lower limb training of several types increases exercise capacity (Rochester, 2003). The motorized treadmill is the most common device used in pulmonary rehabilitation programs (Cucuzzo et al., 2001).

$VO_2^{max}$ is the gold standard measurement of cardiovascular fitness. It provides an objective and reproducible assessment of patient’s functional capacity or exercise capacity (Opasich et al., 2002).

Therefore the aim of this study was to evaluate the therapeutic efficiency of aerobic exercise using treadmill on the burned children’s exercise capacity. As these results may help in planning a physical therapy program, which enhances the improvement of exercise capacity of burned children.

2. MATERIAL AND METHODS

2.1. Subjects:

Thirty children from both sexes and of age 7-17 years with healed partial thickness thermal burn injuries of 20-40% TBSA were included in this study one month after their discharge from hospital. The patients were selected from teaching hospitals in Cairo, Egypt. The study was conducted in the out clinic of the Faculty of Physical Therapy, Cairo University. The faculty’s Human Research Committee approved this study and written informed consents were obtained from the parents of all participants prior to their involvement. Patients were excluded from the study if they had one or more of the following: leg amputation, limitation of range of motion (ROM) of lower limb joints, anoxic brain injury, psychological or severe behaviour disorders (Suman et al., 2002). Patients were randomized into two equal groups; group A (control group) received traditional physical therapy program only (activities of daily living ‘ADL’, stretching, strengthening, and breathing exercises) three times per week for 12 weeks, and group B (pulmonary rehabilitation group) who received pulmonary rehabilitation program inform of aerobic
exercise using a treadmill in addition to their physical therapy traditional program three times per week for 12 weeks.

2.2. Measurement procedures:

Zan-680 Ergospiro “Ergospirometry System” was used to measure patients’ exercise capacity (VO\textsubscript{2max}) and treadmill time in both groups, before and at the end of conducting treatment period (12 weeks). A treadmill exercise test was done by following the Modified Bruce protocol as shown in (Table 1). The mask was fixed by straps then the triple V. tube was connected to the mask. The starting speed and angle of elevation were 1.7 miles/ hour and 0% respectively; they were subsequently increased every 3 minutes. Patients were constantly encouraged to complete 3 minutes for each stage and the test was terminated once the peak volitional effort was achieved (Suman et al., 2002; Suman et al., 2001). The patients were instructed not to tightly grasp the side rails of the treadmill since this leads to decrease VO\textsubscript{2max} and increases the time of exercise (Fletcher et al., 2001).

<table>
<thead>
<tr>
<th>Duration of interval (minutes)</th>
<th>Treadmill speed (miles/hour)</th>
<th>Grade of elevation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1.7</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1.7</td>
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<tr>
<td>3</td>
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<td>3</td>
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<td>5.0</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>5.5</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>6.0</td>
<td>22</td>
</tr>
</tbody>
</table>
2.3. Treatment procedures

Treatment was started one month after the patients’ discharge from hospital for 12 weeks for both groups. RAM model 770 CF electronic treadmill was used for exercising group B at a rate of 3 sessions/week, each session was lasting from 20-40 minutes. The participant exercised at 70-85% of his previously determined individual VO2max (Suman et.al., 2002). Treadmill running exercises at a moderate pace began and ended with warming-up and cooling-down periods in the form of walking on the treadmill for about 3-5 minutes at speed 1-1.5 kilometre/hour with zero inclination. With cooling down the speed was gradually decreased until reaching to zero (Perna et.al.,1999; San Juan et.al.,2007). Traditional physical therapy program for both groups was in the form of stretching and strengthening exercises of all involved areas in addition to diaphragmatic breathing exercises while activities of daily living were performed daily.

2.4. Data analysis

Student’s t-test was used to compare pre and post- treatment program VO2max and treadmill time values within each group. Paired t-test was used to compare both groups. P-value < 0.05 was considered statistically significant. Statistical analyses were performed with Statistical Package for Social Science (SPSS Inc., Chicago, Illinois), version 17 for Windows.

3. RESULTS

3.1. Patients’ demographic data:

Table 2 shows patients’ demographic data, and it demonstrates that there were no significant differences between both groups regarding the patients’ age, weight, height and TBSA.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group (A)</th>
<th>Group (B)</th>
</tr>
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<tbody>
<tr>
<td>Age (years)</td>
<td>12.5±3.1</td>
<td>11.4±3.02</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>38.2±6.55</td>
<td>37.9±6.33</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>137.9±9.2</td>
<td>135.7±10.9</td>
</tr>
<tr>
<td>TBSA(%)</td>
<td>32.89±6.56</td>
<td>29.45±5.11</td>
</tr>
<tr>
<td>Gender (M/F)</td>
<td>9/6</td>
<td>7/8</td>
</tr>
</tbody>
</table>
3.2. Results of control group (group A):

The mean values and standard deviations of VO$_{2max}$ and treadmill time for the control group before and after treatment showed that there were significant improvements in the patients’ VO$_{2max}$ and treadmill time with $P$ value <0.05 and with 26.9% and 25.6% improvement respectively (Table 3).

Table 3. The statistical analysis of mean differences of VO$_{2max}$ and treadmill time pre and post treatment (after 12 weeks) for control group

<table>
<thead>
<tr>
<th>Statistical value</th>
<th>VO$_{2max}$ (mL/Kg/ min)</th>
<th>Time (minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>$X \pm $ S.D</td>
<td>18.98±4.12</td>
<td>24.1±4.21</td>
</tr>
<tr>
<td>t-value</td>
<td>24.3</td>
<td>-10.1</td>
</tr>
<tr>
<td>% of improvement</td>
<td>26.9%</td>
<td>25.6%</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt; 0.05</td>
<td></td>
</tr>
</tbody>
</table>

3.3. Results of pulmonary rehabilitation group (group B):

The mean values and standard deviation are represented in table 4 and showed highly significant improvements in the patients’ VO$_{2max}$ and treadmill time after pulmonary rehabilitation for 12 weeks with 58.6% and 60.5% improvement respectively.

Table 4. The statistical analysis of mean differences of VO$_{2max}$ and treadmill time pre and post treatment (after 12 weeks) for pulmonary rehabilitation group

<table>
<thead>
<tr>
<th>Statistical value</th>
<th>VO$_{2max}$ (mL/Kg/ min)</th>
<th>Time (minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>$X \pm $ S.D</td>
<td>17.9±4.2</td>
<td>28.4±3.2</td>
</tr>
<tr>
<td>t-value</td>
<td>18.56</td>
<td>-18.88</td>
</tr>
<tr>
<td>% of improvement</td>
<td>58.6%</td>
<td>60.5%</td>
</tr>
<tr>
<td>P-value</td>
<td>0.0001</td>
<td></td>
</tr>
</tbody>
</table>
3.4. Comparative Analysis of VO$_2$\text{\textsubscript{max}} and treadmill time between both groups of the study:

Figure 1 shows the mean values of patients’ VO$_2$\text{\textsubscript{max}} and treadmill time for groups A and B at the beginning of the study. The mean values were 18.98±4.12, 17.9±4.2 and 11.22±1.61, 10.94±1.72 respectively. The results represented that, there were no significant differences between both groups for VO$_2$\text{\textsubscript{max}} and treadmill time with P value =0.34 and 0.71 respectively.

![Figure 1](image)

**Figure 1.** The mean value of VO$_2$\text{\textsubscript{max}} and treadmill time at the beginning of study for both groups.

After 12 weeks from the beginning of the study (post treatment) the results showed that there were significance differences regarding the patients’ VO$_2$\text{\textsubscript{max}} and treadmill time between both groups with P value = 0.001. The mean values for group A and B were 24.1±4.21, 14.1±1.23 and 28.4±3.2, 17.56±1.65 respectively (Figure 2).
4. DISCUSSION

The results of the current study pointed out that (1) there was reduction in the burned children exercise capacity represented by reduction in the VO\textsubscript{2max} and treadmill time. This finding is supported by the results achieved by (Mlcak et.al., 1995), who reported abnormal cardiopulmonary functions in a patient survived after thermal injury, in addition to (Suman et.al., 2002; Abd El Baky et.al., 2006; willis et.al., 2011), who documented that there were deteriorations in both pulmonary function and exercise capacity resulting from burn injury, in addition our results showed that (2) there were improvement in the burned children exercise capacity and treadmill time after 12 weeks of pulmonary rehabilitation program in the form of aerobic exercise to the lower limbs using electronic treadmill.

There is a large body of literature supports the effectiveness of pulmonary rehabilitation program especially lower limb aerobic exercise; it is reported that an exercise training program consisted of aerobic exercise of 30-40 minutes duration for 59 patients suffering from obstructive pulmonary disease significantly improved the patient’s peak exercise oxygen consumption (exercise capacity), and work output (Carter et.al.,1988).
Brdareski et.al., 2012 showed that, training involvement two times a week moderate intensity for 15 minutes is enough to achieve some improvement in aerobic capacity. Moreover, improvements in VO$_{2\text{max}}$ and treadmill time were demonstrated following the application of moderate to high intensity aerobic exercise (Punzal et.al., 1991). In addition (Ortega et.al., 2002; Rhoades and Tanner, 2003) concluded that aerobic exercise resulted in improvements in exercise capacity, treadmill time and dyspnea of patients with varying degree of obstruction who experienced low VO$_{2\text{max}}$. Significant increase in patient’s exercise capacity, forced vital capacity (FVC), and forced expiratory volume after 1 second (FEV$_1$) were achieved by the application of pulmonary rehabilitation program consisted of 10 minutes warm up, 25 minutes aerobic exercise and 10 minutes cool down (Finnerty et.al., 2001). (Suman et al, 2002) succeeded to conclude that children with thermal injury also benefit from exercise training, which was evidenced by increase in pulmonary function (PF) and exercise capacity.

It is reported that running, bicycling and other forms of aerobic exercise provide a sufficient stimulus to improve cardio-respiratory function (Porcari et.al., 2002). Similar findings were also supported by (Normandin et.al., 2002; and Rochester 2003), who showed improvement in PF and exercise capacity of patients with obstructive disease.

Several studies had shown that leg exercise program benefits patients with lung disease. Peripheral muscle training on treadmill has proven to be a valid tool for improving symptoms of dyspnea, quality of life, and capacity for exercise in patients with chronic obstructive pulmonary disease (COPD) (Ruiz de Oña Lacasta et.al., 2004). (Janos et.al., 2005) concluded that, lower extremity training for 8 weeks caused improvement in exercise capacity and dyspnea reduction measured with Modified Borg Scale.

Improvement in the VO$_{2\text{max}}$ may be due to an increase in the blood flow to the active muscle mass because of an increase in maximal cardiac output and the changes within muscle also contribute to this increase, primarily the increases in capillarization, myoglobin and oxidative enzyme activity (Bouchard et.al., 1999). In addition, it was suggested that the significant increase in VO$_{2\text{max}}$ might be related -in part- to the effect of aerobic exercise that improves the respiratory function and - on the other hand- to an increase in the stroke volume of the heart by the effect of regular exercise. These respiratory adaptations facilitate oxygen supply to tissues and add further evidence to the improvement of respiratory fitness (Carsten et.al., 2004). Recently (Kolt and Snyder-Mackler, 2007) concluded that The mechanism underlying improvement in VO$_{2\text{max}}$ after aerobic training may be attributed to improved
central adaptations (increased heart rate and stroke volume at maximal exercise would produce elevated cardiac output) along with peripheral adaptations (improved cardiac output redistribution, improved endothelial function, increased capacity of the muscle to extract oxygen owing to an increase in capillary density). Additional benefits of increased capillary density include decreased diffusion distance, and increased red blood cell transit time, providing enough time for oxygen diffusion which is facilitated by the increase in the number of mitochondria that increase the surface area for oxidation. Also, temperature elevation and decreased pH in the active muscle facilitate oxygen unloading from haemoglobin. The combined effects of increased capillarity and enhanced oxygen unloading result in an increase in the arteriovenous oxygen difference. Current theory states that, the increases in the arteriovenous oxygen difference and increases in cardiac output contribute equally to the increased VO$_{2\text{max}}$ observed after aerobic training.

The results of this study and previous studies prompt us to conclude that addition of aerobic exercise to the traditional rehabilitation program is effective means for improving burned children exercise capacity rather than application of the traditional rehabilitation program alone.

5. ACKNOWLEDGMENTS

We would like to acknowledge the contribution of physical therapy faculty’s members to accomplish this work. We would also like to thank the participants for their involvement.

6. REFERENCES


Ortega, F., Toral, J., Cejudo, P., Villagomez, R., Sanchez, H., Castillo, J., and


Evaluation of Low Level Laser Therapy with Different Types on Recurrent Aphthous Stomatitis: A Randomized Control Study

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Abstract: Recurrent aphthous stomatitis (RAS) is the most frequent ulcerative lesion of the oral cavity which is associated with pain. Low level laser therapy (LLLT) has been evaluated for its effectiveness in pain reduction and acceleration of ulcer healing. The purpose of this study was to determine the effect of LLLT on RAS in addition to, compare the effect of Helium Neon laser (He-Ne) and Gallium Aluminum Arsenide laser (Ga-Al-As) on pain modulation and healing process in RAS. A total of 45 patients of both sexes, with RAS were included in the current study. The patients were divided randomly into three groups (15 patients in each group); group A (He-Ne, 632 nm, 1.56 mW, 1.22 J/cm²), group B (Ga-Al-As, 830 nm, 50 mW, 6.3 J/cm²) and group C (medical treatment group). Both pain and size of ulcer diameter were evaluated before and after treatment by three days. The results showed significant reduction in pain scores in group A and B (P< 0.05) while non-significant reduction was recorded in group C (P= 0.21) with percentage of improvement 82.53%, 61.72% and 6.6% respectively. However ulcer diameter results represented that the percentages of improvement were 86.27%, 65.01% and 10.41% for group A, B and C respectively. He-Ne laser is effective than Ga-Al-As laser in management of RAS.

Keywords: Recurrent aphthous stomatitis, LLLT, Ulcer size, Pain.

Introduction

Recurrent aphthous stomatitis (RAS), canker sores or Aphthous ulcer is the most common ulcer in oral cavity. The prevalence of RAS ranges from 5-60% of the population all over the world.³ It is characterized by recurrent, painful, multiple or a single shallow, ovoid or round ulcer as well as, it usually appears as erythematous haloes with grey or yellow floors. RAS has three clinical forms which are minor, major and herpetiformis.¹ The exact etiology of this lesion is unknown, but it may be related to autoimmune condition. In addition, there are some precipitating factors that have a role in the etiology of Aphthous as; genetic factors, trauma, stress, deficiency in vitamin B1, B2, B6 or B12, cessation of smoking or systemic diseases. Moreover thermal injury or chemical irritation may contribute to develop RAS.³⁵⁶. The manifestations range from mild to severe, however it causes moderate to severe pain and burning sensation that may interfere with the person ability to eat, ingest food, drink, or speech.³ Healing process duration differs according to the RAS form. As it lasts up to 7-14 days in minor form, 15 days in the Herpetiform form, while in the sever form it may take about 20-30 days.³⁸.
Numerous treatment modalities have been used to control RAS lesions. Many drugs have been described as topical corticosteroid, antibiotics and topical anesthetics. Recently laser therapy has been used to manage these cases. Laser is defined as "an acronym for Light Amplification by Stimulated Emission of Radiation." Low-level laser therapy (LLLT) is also known as 'soft laser therapy' or bio-stimulation. It is usually settled in wave length of 650-1200 nm. He-Ne laser (633nm) and Ga-Al-As laser (780-820-870nm) are types of low level lasers. Several studies reported the benefits of LLLT on pain reduction in addition to promote healing process in RAS by different mechanisms. Maiya et al. succeeded to demonstrate the effectiveness of He-Ne laser in management of RAS. Recently, Albrektson et al. represented also that Ga-Al-As laser has beneficial effect in the healing of recurrent aphthous ulcers.

To our knowledge there is no study has been conducted to compare the effect of LLLT with different types (He-Ne and Ga-Al-As laser) on pain modulation and healing process in RAS. Therefore, the aim of this study was to assess and to compare the efficacy of different types of LLLT on reduction of pain and ulcer size in the cases of recurrent aphthous ulcers.

Methods

Subjects

Of 50 eligible patients, 45 patients of both sexes, with recurrent aphthous stomatitis (RAS) in their oral cavity, accepted to participate in the current study. Patients were referred by the teaching hospital of the college of Dentistry, Cairo University. The participants with the following inclusive criteria were enrolled in this study; (1) Aged 20-40 years; (2) Patients had pain and redness at the ulcer site; and (3) Enrolment of the patients within 2 days after the appearance of ulcer. Exclusion criteria included patients presenting with chronic non healing ulcers or any systemic diseases that might be a cause of RAS, or smokers.

Measurement procedures

Both pain and size of ulcer were evaluated at the baseline, and after three days post treatment.

Figure 1. The Participants Flow Chart

The study was conducted in the out-patient clinic of the faculty of Physical Therapy, Cairo University, after the approval of the Postgraduate Institutional Ethical Committee at faculty of Physical Therapy, Cairo University. Each patient was informed about the procedure and technique, and his/her consent was obtained.

Participants who had fulfilled the eligibility criteria were randomized to three groups (15 patients in each group); group A (He-Ne laser group), group B (Ga-Al-As laser group) and group C (control group).
Pain measurement

The patients were asked to grade their pain by using visual analogue scale (VAS). VAS is a horizontal 10 cm line with 0 represented no pain and 10 is used to describe maximum pain.\(^\text{15}\)

Size of ulcer measurement

A calibrated periodontal probe was used to measure the ulcer's size while the patients were placed in a comfortable sitting position. The probe is a long, tapered, rod like tool that is calibrated in millimeters with a tip.\(^\text{16}\)

Treatment procedures

**He-Ne laser therapy**

Helium-neon laser (ASA srl laser system) was applied to group (A) with the following parameters: as 632 nm, 1.22 J/cm\(^2\) and 1.56 mW.\(^\text{13}\)

**Ga-Al-As Laser Therapy**

Ga-Al-As laser device (Doctor Smile Diode Laser, Italy) with 830 nm, 6.3 J/cm\(^2\), power output of 50 mW was applied to group (B).\(^\text{17}\)

Prior to the application of laser therapy the patient and the therapist wore a protective eyewear. Patient was placed in comfortably sitting position. Laser therapy was conducted for one sitting that consisted of four sessions. Treatment lasted for 45 seconds, with a gap of about 30-60 seconds between each session. Total laser application time was about three minutes. Non-contact mode was used with a distance of 2-3 mm between the laser tip and the ulcer surface. The laser beam was applied in a continuous sweeping and circular motion.\(^\text{2}\)

Medical Treatment

Patients received Salivex-L Paint 10ml (Anthraquinone glycosides 500 mg + Salicylic acid 100 mg + Lidocaine hydrochloride 60 mg) every 6 hours per day for group C.

Data Analysis

Data were analyzed with Statistical Package of Social Science (SPSS) version 22.0. The data were compiled together and they were evaluated. Means, standard deviations, paired t-test, ANOVA test and P values were calculated. Statistical significance was set at P < 0.05. Percentage of improvement was calculated using the formula of post-pre/pre*100.

Results

The study comprised of a total of 45 patients, of which 22 were males and 23 were females. All the patients completed the study. Table 1 shows the distribution of sex and age among groups and it represents that there were no significance differences between the patients' sex and age with P= 0.92 and 0.80 respectively.

The statistical analyses of the pre and post measurements of ulcer diameter for all groups are represented in table 2. The results shows that there were significant reduction differences between the baseline and after 3 days post treatment diameter measurements for group A and B with P< 0.05, while there was no significance difference between measurements in control group with P= 0.21. The percentages of improvement were 86.27\%, 65.01\% and 10.41\% for He-Ne group, Ga-Al-As group and control group respectively.

In table 3 the mean of reduction in the VAS scores are demonstrated. The results of pain scores showed significant reduction between the pre and post measurements in group A and B (P< 0.05) with percentage of improvement 82.53\%, 61.72\% respectively. In addition to, no significance difference was observed in group C measurements (P= 0.32) and the percentage of improvement was 6.6\%.
Table 1. Demographic data of the patients

<table>
<thead>
<tr>
<th>Variables</th>
<th>Groups</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
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<tbody>
<tr>
<td>Gender</td>
<td></td>
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<td>Female</td>
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<tr>
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<td>7</td>
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<tr>
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<td>7</td>
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</tr>
<tr>
<td>Age</td>
<td></td>
<td>29.07±6.05</td>
<td>29.40±6.631</td>
<td>27.87±7.13</td>
</tr>
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</table>

Table 2. Statistical analysis of ulcer diameter in all groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>Groups</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean± SD</td>
<td>Group (A)</td>
<td>5.90±1.23</td>
<td>0.81±0.39*</td>
</tr>
<tr>
<td></td>
<td>Group (B)</td>
<td>5.63±1.29</td>
<td>1.97±0.54*</td>
</tr>
<tr>
<td></td>
<td>Group (C)</td>
<td>5.57±1.49</td>
<td>4.99±1.43</td>
</tr>
</tbody>
</table>

±SD : standard deviation , *Significant (P < 0.05) improvement between the pre and post measurements

Table 3. Statistical analysis of VAS scores in all groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>Groups</th>
<th>Pre</th>
<th>Post</th>
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</thead>
<tbody>
<tr>
<td>Mean± SD</td>
<td>Group (A)</td>
<td>6.47±1.06</td>
<td>1.13±0.64*</td>
</tr>
<tr>
<td></td>
<td>Group (B)</td>
<td>6.27±1.39</td>
<td>2.40±1.06*</td>
</tr>
<tr>
<td></td>
<td>Group (C)</td>
<td>6.07±1.56</td>
<td>5.67±1.45</td>
</tr>
</tbody>
</table>

±SD : standard deviation , *Significant (P < 0.05) improvement between the pre and post measurements

Fig 2. Ulcer diameters in all groups

Fig 3. VAS pain score in all groups
Fig 2. represents the statistical analysis of ulcer diameter among groups where, there was no significance difference among the baseline measurements of all groups with P= 0.77. Moreover the post treatment measurements demonstrated significance difference among groups with P< 0.001.

The results of pain scores by VAS concluded that the pre measurements among groups were not significant with P= 0.89, while after three days the post measurements showed significant difference among groups (P< 0.001), Fig 3.

Discussion:

The current study provides evidence that a single session of LLLT is effective in management of RAS than conventional medical treatment, as the results showed significant reduction of pain score and ulcer diameter with the application of LLLT in group A and B than group C.

Recently, LLLT was suggested to be one of the important treatment modalities for wound repair processes and pain control. Clinical and laboratory studies explained different mechanisms through which LLLT can accelerate wound healing. These mechanisms includes: local vasodilatation and increased of blood flow, cellular bio-stimulation, in addition to analgesic and anti-inflammatory effects.

Moreover, researchers claimed that LLLT is effective in pain reduction and they provided some explanations such as: the role of LLLT in increasing the production of opioid peptides, decreasing the histamine release, reducing the prostaglandin and bradykinin production, increasing local circulation and oxygen supply, as well as blocking of the action potential generation in the primary afferent neuron.

The results also showed that He-Ne laser was more effective than Ga-Al-Ar in management of both pain (82.53% and 61.72% respectively) and ulcer diameter (86.27% and 65.01% respectively).

It was shown that He-Ne laser exerts analgesic, anti-inflammatory and regenerative effects in managing chronic RAS. Many investigators examined the effect of He-Ne laser in management of RAS ulcer. Earlier, Kitchen and Bazin stated that He-Ne laser (632 nm, 1.56 mW and 1.22J/cm²) was effective in controlling pain and healing of recurrent aphthous ulcers. Furthermore, Maiya et al examined He-Ne laser with the same parameter on thirty patients complaining from minor RAS and they recorded its efficacy in reducing pain, lesion size and healing time, while Anand et al applied the same parameters on patients suffering from major RAS and they reported that lesions healed completely within 3-4 days with reduction of pain and lesion recurrence.

De Souza et al conducted a comparative study between the effect of He-Ne laser and conventional medical treatment on RAS, where both treatments were applied until the disappearance of the lesions. The results showed that He-Ne laser is superior to medical treatment in its analgesic and healing effects with regard to RAS. Recently, Aggarwal et al also confirmed the effectiveness of He-Ne laser in relieving pain and reducing the healing time of patients suffering from aphthous ulcers.

On the other hand, several researchers preferred using Ga-Al-As laser to control pain and promote healing process in patient suffering from RAS. Earlier, Rocha Junior et al examined the effects of Ga-Al-As laser with a wavelength of 830 nm, 50 mW power output and a dose of 6.3 J/cm² on ten patients with recurrent aphthous ulcers and the results showed significance reduction in pain as well as healing time. Furthermore Ga-Al-As laser was diagnosed for its efficacy in preventing recurrence of minor RAS. As, kjuhn et al reported that a single sitting of 830 nm Ga-Al-As laser can effectively reduce the healing time, pain severity, size, and recurrence of the lesion in patients with minor RAS. Recently, the same results were supported by Albrektson et al who tested the same parameters of Ga Al As semiconductor laser but for three consecutive days.

According to our results, He-Ne laser appeared to be superior to Ga-Al-As laser in management of RAS. This is in consistence with the findings of the study that conducted by Reddy, as he reported that the biomechanical and biochemical analysis of healed wounds determined that He-Ne laser resulted in greater healing effects than Ga-Al-As laser.
It is suggested that the LLLT wavelength have an important role in the results related to RAS treatment.\textsuperscript{31} Furthermore, it is concluded that He-Ne laser would accelerate wound healing with significant collagen fibers production and deposition\textsuperscript{32,33}, combined with rapid neovascularization and re-epithelization.\textsuperscript{34} As well as, the results may be attributed to the He-Ne and Ga-Al-As laser photochemical interaction with cells, as it was suggested that the absorption of radiation emitted by He-Ne laser at 632 nm begins at the components of respiratory chain, whereas it starts at the membrane level with the radiation emitted by the Ga-Al-As laser at 830 nm, which leads to photochemical response of the tissue.\textsuperscript{35} Earlier, Sommer et al\textsuperscript{35} concluded that high significant biological effects were expected with predominant dose values of LLLT, i.e. up to 5 J/cm\textsuperscript{2}. Moreover, it is suggested that higher doses reduce cell proliferation as well as it may damage cell membrane.\textsuperscript{36}

In addition to, Reddy reported that the differences in coherent properties of lasers may also affect healing process, as it is known that the radiation emitted by the He-Ne laser has more coherence in its nature than that of the radiation emitted by the Ga-Al-As laser, and he added that these specific differences in the absorption of radiation by tissue and discrepancies in coherence properties may explain some of the variations between the He-Ne and Ga-Al-As lasers in promoting wound healing.\textsuperscript{36} Furthermore, we also suggest that the results may be affected by patient's cooperation.

The current study may be limited by the small sample size, which limits generalization. Therefore, large sample size is recommended.

**Conclusion:**

Based on the finding of this study, it is concluded that LLLT is effective than medical treatment in reducing pain and promote healing of RAs. Furthermore He-Ne laser was observed to be superior to Ga-Al-As Laser in management of RAS. Further studies are needed to evaluate the influence of LLLT with different wavelength, output powers and energy densities.

**Acknowledgement**

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**Conflict of interest**

The authors have no conflicts of interest to disclose.

**References**


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Impact of Aerobic Exercise on Physical Fitness and Fatigue in Children with Acute Lymphoblastic Leukemia

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ABSTRACT

Background: Acute lymphoblastic leukemia (ALL) is one type of childhood cancer. In the past decades, cure rates of ALL have increased and the survivor's quality of life and physical fitness have become a growing concern. Furthermore, cancer-related fatigue (CRF) is reported to be the most distressing symptom in cancer. Objective: We aimed to examine the effect of aerobic exercise on the physical fitness and fatigue in children suffering from ALL. Methods: Thirty patients of 8 to 16 years with ALL participated in this study. Participants were randomized to study group (Group A), who participated in supervised aerobic exercise program in addition to home program, and control group (Group B), who were instructed to maintain their usual level of activity in addition to home program. Measurement of physical fitness and fatigue were done at the baseline and after 16th weeks. Results: Post measurement results suggested that, there was significance difference between both groups (P < 0.05). The percentage of improvement of physical fitness and fatigue level for group A was 31.06% and 21.56% respectively, while the percentage of improvement for group B was 4.16% and 2.78% respectively. Conclusion: Aerobic exercise is effective in improving physical fitness and management of CRF in children with ALL.

Key Words: Acute lymphoblastic leukemia, Cancer related fatigue exercise training, Physical fitness.
aerobic exercise to home program on both physical fitness and cancer related fatigue in children with Acute Lymphoblastic Leukemia.

METHODS

Study Design:
This is a prospective, randomized controlled study. It was conducted in the Cardiorespiratory Lab at Faculty of Physical Therapy, Cairo University, Giza, Egypt. The study was approved by Postgraduate Institutional Ethical Committee at Faculty of Physical Therapy. Each patient and their parents individually received written and verbal information about the study. Written informed consent was obtained from the parents or legal guardian of each patient, and also from each patient aged 12 years and older.

Participants
Of 36 eligible patients, 30 patients (boys and girls) with Acute Lymphoblastic Leukemia agreed to participate in this study. The patients were referred by an Oncologist from Children’s Cancer Hospital Foundation 57357 to participate in this study. They were chosen on the basis of the following criteria: 1) Patients’ age from 8 to 16 years, 2) Patient complained from fatigue, 3) There were absence of musculoskeletal disturbances that may limit participation in the exercise training program, 4) Preserved cardiac structure and function, as assessed by an echocardiogram, 5) Ambulant without need for human assistance in addition to 6) The elapsed time since their last chemotherapy had to be at least 6 months. Children were excluded when they suffered from cardiovascular disease, acute or chronic respiratory disease, acute or chronic bone, joint, or muscular abnormalities, or immune deficiency that might compromise the patient’s ability to participate in the exercise rehabilitation program.

Participants who had fulfilled the eligibility criteria were randomized using simple randomization method to either study group (Group A) (n= 15, 8 boys and 7 girls), who participated in supervised moderate intensity aerobic exercise program in addition to home-based exercises, and control group (Group B) (n= 15, 9 boys and 6 girls), who were instructed to maintain their usual level of activity as well as to perform home-based exercises, Fig. 1

Measurement procedures
Assessment for both physical fitness and fatigue were done at the baseline and after 16th weeks.

Physical fitness measurement

$\text{V0}_{2}\text{max}$ was used to measure the patient's physical fitness. Participants performed a Graded Exercise Test (GXT) on treadmill using the modified Bruce protocol, table (1).

Patients were constantly asked to complete 3 minutes for each stage and once the peak volitional effort was achieved the test was terminated [15,17]. During GXT, the patient breathed through a face mask (Hans Rudolph Inc, Kansas City, MO, USA) that connected to a calibrated expired gas analysis system (Zan-680 Ergospiro Ergospirometry System, manufactured by ZAN Me Bgerate GmbH, Germany). Gas analyzers and flow meter were connected to a computer and calculate oxygen uptake. Heart rate (HR) was monitored continuously during the graded exercise test. $\text{VO2}_{\text{max}}$ was calculated as the average value over the last 30 seconds during the exercise test [18].

Fatigue measurement:
Fatigue level was assessed by the subscale fatigue of The Checklist Individual Strength (CIS) [19]. Earlier the CIS was used to investigate cancer survivors [20,21]. It is reported as a useful and a valid multidimensional instrument, for both assessment and scoring. CIS is designed to measure four aspects of fatigue; subjective experience of fatigue, concentration, motivation, and physical activity. It consists of eight items scored on a seven-point Likert Scale, with scores ranging from eight to 56 (with 1 indicating best and 7 worst function) [22,23].

Exercise Intervention

Aerobic exercise:
Group (A) started aerobic exercise program approximately 24 hours after assessment and lasted for 16th weeks in addition to home-based exercises. An exercise session would be only cancelled if a patient was experiencing fever (temperature > 38°C/100.4°F), low blood platelet levels (< 50.000 per μl), a neutrophil count lower than 500 cells per μl, marked anemia (hemoglobin < 8 g/dl) or severe cachexia (i.e., weight mass loss > 35%) [24]. Patients had participated in a supervised aerobic exercise program by one of the
researcher (3 sessions /week with each session lasting from 20–40 minutes). A RAM model 770 CF electronic treadmill was used for aerobic exercise. Each participant exercised at 70–85% of his/her previously determined individual VO$_{2\text{max}}$. The exercise program was divided into 5 min stretching exercise, warm up period, followed by moderate intensity of aerobic exercises, and finishing with a cool down period. Warming-up and cooling down periods were in the form of walking on the treadmill for about 5–10 minutes at a speed of 1–1.5 km/h with zero inclination. In the cooling down period, the speed was gradually decreased until reaching zero [7]. Participants were regularly monitored throughout the exercise program, and their heart rates were recorded during the exercise sessions.

**Home program:**

The children in both groups were instructed to exercise at home for at least two times per week. The exercises were outlined by photos, and verbally by us at the first session. Furthermore parents were asked to supervise the home exercises. The home training program was based on the ‘Royal Canadian Air Force Exercise Plans for Physical Fitness’ and was composed of five basic exercises to enhance strength, flexibility and aerobic fitness. At each home training session the children accomplished five exercises a given number of times in 11 min, stepwise increasing intensity and the number of times during the 16th weeks [25]. The children or their parents were asked to record training frequency and training progression.

**Data Analysis:**

Data were analyzed with Statistical Package of Social Science (SPSS) version 22.0 (Chicago USA). Normal distributed data (Kolmogorov-Smirnov test, P > 0.05) were expressed as mean and standard deviation (SD). The paired t-test was used to compare variables at the baseline and after 16th weeks within each group, while independent t-test was used to compare variables between both groups. For fatigue level nonparametric statistical analysis was used including the Wilcoxon Signed Rank test for variable comparison within groups and the Mann-Whitney U test for comparison between groups. All P-values in the analysis were considered statistically significant when P < 0.05.

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**Table 2** summarizes the demographic characteristics of the participants in both groups. A total of 30 patients (17 boys and 13 girls) with Acute Lymphoblastic Leukemia were involved in this study. No significant differences were observed between both groups regarding age (P=0.853), weight (P=0.935), height (0.57), BMI (P=0.895) as well as the elapsed time since the patients’ last chemotherapeutic treatment (P=0.798).

Table 3, reports the mean values of the pre and post VO$_{2\text{max}}$ measurements for both groups. There was a significant difference between the pre and post VO$_{2\text{max}}$ for group A with a percentage of improvement 31.06% (P < 0.05), while no significant difference was recorded between them for group B with 4.16% (P < 0.05).

For fatigue scores (CIS), the results demonstrates significance improvement in the post CIS for group A (P < 0.05) with 21.56 %, while there was no significant difference between the pre and post measurements for group B with percentage of improvement 2.78% (P > 0.05), Table 4. Fig. 2 shows that there was no significant difference between the pre measurements of VO$_{2\text{max}}$ for both groups, while the post measurements represented a significance difference with (P< 0.05). As well as, the results represents no significance difference between
the pre fatigue scores of both groups (p= 0.97), while there was significance difference in the post fatigue scores (P< 0.05), fig 3.

Table- 2. Statistical analysis of demographic characteristics of patients in both groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group</th>
<th>M±SD</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>GA</td>
<td>12.51±3.40</td>
<td>-0.185</td>
<td>0.853*</td>
</tr>
<tr>
<td></td>
<td>GB</td>
<td>13.2±3.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (m)</td>
<td>GA</td>
<td>1.25±0.2</td>
<td>-0.568</td>
<td>0.570*</td>
</tr>
<tr>
<td></td>
<td>GB</td>
<td>1.27±0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>GA</td>
<td>40.59±6.97</td>
<td>-0.092</td>
<td>0.935*</td>
</tr>
<tr>
<td></td>
<td>GB</td>
<td>41.90±9.19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>GA</td>
<td>19.70±3.04</td>
<td>-0.154</td>
<td>0.895*</td>
</tr>
<tr>
<td></td>
<td>GB</td>
<td>19.99±2.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elapsed time</td>
<td>GA</td>
<td>7.90±1.75</td>
<td>-0.269</td>
<td>0.798*</td>
</tr>
<tr>
<td></td>
<td>GB</td>
<td>8.1±1.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data are presented as the mean (SD), * not significant

Table- 3. Statistical analysis of aerobic capacity variables within each group

<table>
<thead>
<tr>
<th>Variables</th>
<th>Groups</th>
<th>Pre</th>
<th>Post</th>
<th>% of improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO_{2max}</td>
<td>GA</td>
<td>25.56±4.50</td>
<td>33.50±3.72</td>
<td>31.06 %*</td>
</tr>
<tr>
<td></td>
<td>GB</td>
<td>25.25±4.69</td>
<td>26.30±4.70</td>
<td>4.16 %</td>
</tr>
</tbody>
</table>

Data are presented as the mean (SD), *Significant (P < 0.05) improvement between the pre and post measurements.

Table-4. Statistical analysis of fatigue within each group

<table>
<thead>
<tr>
<th>Variable</th>
<th>Groups</th>
<th>Pre</th>
<th>Post</th>
<th>Z</th>
<th>% of improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue</td>
<td>GA</td>
<td>43.60±4.5 (37-51)</td>
<td>34.20±4.94 (30-44)</td>
<td>-2.823^a</td>
<td>21.56 %*</td>
</tr>
<tr>
<td>CIS-score</td>
<td>GB</td>
<td>43.20±5.4 (38-54)</td>
<td>42±5.34 (38-54)</td>
<td>-1.732^a</td>
<td>2.78%</td>
</tr>
</tbody>
</table>

*Significant (P < 0.05) improvement between the pre and post measurements, a. Wilcoxon Signed Ranks Test
DISCUSSION

The main findings of the present study reported a significant improvement of both physical fitness and fatigue level in children who survived ALL by adding a 16-week of aerobic exercise training program to home exercise program.

There is growing evidence for the positive effects of aerobic exercise training on physical fitness, fatigue and physical well-being of children during and after treatment for cancer [19, 26, 27, 28].

Regarding the physical fitness, a study conducted by San Juan et al., [7] supported our results, as he reported positive results of a 16-week supervised aerobic exercise program among children with ALL. Moreover, Adamsen et al., [29] showed that a high-intensity exercise program for 6 weeks led to improvement in VO\textsubscript{2max} by 16% in patients who suffering from cancer including leukemia. Earlier, Sharkey et al.,[30] examined the efficacy of a 12-week aerobic training program on the peak oxygen uptake among childhood cancer survivors and he also reported an improvement in the patients’ peak oxygen uptake. Furthermore a pilot study conducted by Kolden et al., [31] on women who had breast cancer, they suggested significant improvement in cardiorespiratory fitness after completion of a 16-week exercise training.

In contrast Marchese et al., [32] evaluated the effect of four months of exercise on cardiovascular response in children with ALL who received maintenance therapy. They failed to show improvement in the cardiovascular response assessed by a nine minute run walk test. Moreover, Takken et al.,[14] found no cardiopulmonary response to 12-week community-based exercise training program in 9 children with ALL (aged 6–14 years) as assessed by standardized cardiopulmonary exercise testing. Recently, Alibhai et al.,[33] decided significant improvements in 6MWT distance post-exercise (p=0.006) within group but no significant improvement were recorded for VO\textsubscript{2max} (p=0.486).

This inconsistency across the literatures might be related to the variability in the population’s age, evaluation time post chemotherapy treatment, the intensity, and duration of the intervention.

It was suggested that increasing in aerobic capacity by aerobic exercise program may due to the effect of aerobic exercise on respiratory function and the stroke volume of the heart. These respiratory adaptations help facilitation of oxygen supply to tissues which lead to the improvement of respiratory fitness [34].

Our results are in consistent with prior studies that reported highest level of fatigue during and immediately following cancer treatment [35]. Moreover it was determined that improvements in aerobic fitness have been accompanied with improvement in fatigue level [29, 36, 37]. These agreed with the findings of Adamsen et al., [29], where they reported significant improvement of cardiovascular capacity (VO\textsubscript{2max}) of
eighty-two patients suffering from various cancers with significant reduction in fatigue. 

Significant reduction in fatigue level in response to exercise programs of various modes, designs, intensities, duration, and with different types of cancer patients was reported in many studies [36, 38, 39]. Recently, Yeh et al.[40] recorded reduced levels of fatigue (P = 0.03, Cohen’s d = 0.54) among children with ALL, who completed a 6-week home-based aerobic exercise program when compared to a control group, as well as Blaauwbroek et al.[41] demonstrated reduced levels of fatigue with increased levels of physical activity (P < 0.005, Cohen’s d = -0.92 and 0.94 respectively) after 10 weeks of a homebased physical activity in childhood with cancer survivors. In addition to the results of a study by Keats and Culos-Reed [42] who revealed a reduction in fatigue (P = 0.01, Cohen’s d = 0.69) after a 16-week group of physical activity intervention in survivors of pediatric cancer.

The current study has several limitations including: First, the relatively small sample size therefore a large sample size is needed to be studied. Second, the subjects were recruited from only one regional center, thereby limiting generalization. Finally, lack of follow-up after the intervention period, so further researches are needed for following up measurements. Moreover this study can be further extended by conducting on patients with different types of cancer.

Conclusion

The results of our study suggest that adding supervised aerobic exercise to home program is an effective approach to improve physical fitness and fatigue level in children with ALL. Therefore, these results can guide therapists in creating rehabilitation programs that focus on the specific difficulties faced by patient undergoing chemotherapy.

Acknowledgement

We would like to acknowledge the contribution of physical therapy faculty’s members to accomplish this work. As well as, all thanks to the Children’s Cancer Hospital Foundation 57357 for their supports.

Conflict of interest

The authors have no conflicts of interest to disclose.

References


Low Frequency Ultrasonic Versus Microcurrent Effect on Tissue Healing After Tendon Suture

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ABSTRACT
Background: Tendon injury has poor healing process. Therapeutic US has a positive role to play in providing the growth factors, also Microcurrent therapy has been used to increase the rate of healing.

Purpose: This study was conducted to investigate the difference between high frequency ultrasound versus microcurrent therapy on the tissue healing of Achilles tendon after suture.

Methods: Thirty female albino rats were surgically transected Achilles tendons, were randomly and assigned into three groups with ten rats in each group (group I served as a control, group II was treated with high frequency US and group III was treated with microcurrent). The treatments were administered with ultrasound and microcurrent day other day starting immediately from the day after injury for 5 weeks. Wound size measurements were evaluated till complete healing.

Results: Both low frequency ultrasonic and microcurrent have a significant effect on decreasing wound size where the mean value of the wound treated with low frequency ultrasonic decreased from 0.2 mm ± 0.03 to 0.0 mm in the fifth time of measurement while the wound size of the control group decreased from 0.2 mm± 0.08 mm in the fifth time of measurement. Comparing wound size in Micro-current group among the times of measurements Vs the control has shown a significant decrease of wound size where the mean value decreased from 0.2 mm ± 0.06 to 0.0 mm in the fifth time of measurement. The t test of group II has shown significant decrease in wound size measurement where the t value and P value showed that it was significant during 3rd and 5th times of measurement. The t test of group III has shown significant decrease in wound size measurement where the t value and P value showed that it was significant during 2nd, 3rd and 5th times of measurement.

Conclusion: Low frequency ultrasonic has more significant effect than microcurrent on decreasing wound size after tendon suture.

Keywords: Ultrasound, Microcurrent, Achilles tendon, Tissue healing.
INTRODUCTION

Tendons are metabolically active tissues requiring vascular supply but, in some (Achilles tendon, tibialis posterior and supraspinatus), hypovascular or watershed areas have been identified \(^{(1)}\). Tendons receive their blood supply from three main sources: the intrinsic systems at the myotendinous junction and osteotendinous junction, and the extrinsic system through the paratenon or the synovial sheath \(^{(2,3)}\).

Tendon degeneration may lead to reduced tensile strength and a predisposition to rupture. Indeed, histological evaluation of ruptured Achilles tendons has demonstrated greater degeneration than was found in tendons that were chronically painful as a result of an overuse injury \(^{(4)}\). The golden aim of the repair of tendon injury is to achieve a permanent repair that could reestablish the smooth mobility of the regenerating tendon and to have significant tensile strength loads \(^{(5,6)}\).

The healing process is a balance between the intrinsic and extrinsic healing processes. The mechanism for achieving this balance may lie in the differential ability of the cells to respond to local factors \(^{(7)}\). The penetration (or transmission) of ultrasound (US) is not the same in each tissue type, it is clear that some tissues are capable of greater absorption of US than others. Generally, the tissues with the higher protein content will absorb US to a greater extent, then tissues with high water content and low protein content absorb little of the US energy (e.g. blood and fat) while those with a lower water content and a higher protein content will absorb US far more efficiently. Tissues can be ranked according to their relative tissue absorption and this is critical in terms of clinical decision making \(^{(8)}\).

During the proliferative phase (scar production) US also has a simulative effect (cellular up regulation), though the primary active targets which are now the fibroblasts, endothelial cells and myofibroblasts cells \(^{(8,9,10)}\). It also enhance fibroplasia and collagen synthesis \(^{(11,8)}\). (Therapeutic US has a positive role to play in providing the growth factors \(^{(12,13)}\).

Micro electrical current stimulation (MES) is a physical therapy modality providing electric current in millionths of an ampere \(^{(14)}\). MES appears to play a significant role in the healing process, as it can promote healing in variety of bone and skin lesions. The evidence for other tissues is encouraging but presently scant. MES uses electric currents similar to those produced by the body during tissue healing. It may be particularly beneficial where endogenous healing has failed \(^{(15)}\). An effective mean of promoting tendon healing either an US or electrical stimulation will be the concern of this study.

METHODOLOGY

Instrumentation:

- Ultrasound apparatus: Sonopuls 464 ultrasound unit manufactured by Enraf-Holland; pulse repetition rate 100 Hz; pulse duration 2 ms; model 1464-900; serial number 9-043
- MES apparatus was used to deliver microcurrent stimulation, model: EMSI-4250, serial no.:A358612, made in Taiwan.
Plastic sheet: was used to measure the wound size and wound total circumference, before MES application and every session during the treatment period.

Q tips to measure depth of the wound.

Surgical Procedures
Following the protocol of Sharifi et al., (2007)\(^{(16)}\).

Preparation of the animals
In preparation for surgery, the rats were fasted 12 hours for food while water was withheld 3 hours only before the operation. Immediately before the surgery the hair was removed from the site of the operation, at the posterior and medial aspects of the hind limb using hair removal cream, the remaining hair was short cut using hair scissor. Each rat was weighed before the operation to determinate the dose of anestesia.

Anesthesia
On the day of surgery each rat was weighed and anesthetized by general anesthesia using intramuscular injection of ketamine hydrochloride (35 mg/kg body weight) (Ketalar (Parke _Davis SA Barcelona _Spain) and Xylazin hydrochloride (5 mg/kg body weight) (Rompun 2% (Bayer Leverkusen, Germany).

Surgical Technique
All surgical techniques were done under complete standard sterile conditions. The animal was immobilized on the surgical table in a prone position. Achilles tendon of right hind limb of each rat was exposed and isolated, through about 3cm of incision at the hind limb. Achilles tendon was sharply transected with a scalpel, about 1cm apart from calcaneal insertion Each end of the served Achilles tendon was approximated and immediately sutured by 4/0 proline (Ethicon, NJ, USA) using modified Kessler suture technique. The skin was then left opened. Afterward, the operated hind limb was immobilized using plaster of Paris cast leaving opening for E.S.

Immobilization
After tenotomy and suture, the served hind limb was immobilized in a plaster of Paris cast. The cast extended from mid-thigh to the toes, with the knee in flexion and ankle held in 45 degree of planter flexion to make the calf muscles in shortened position. A window was done at the site of tenotomy for wound dressing and MES application in the treatment groups.

All animals were returned back to cages and were injected intra-muscularly by prophylactic antibiotic.

Treatment procedures
- Before treatment the skin was cleaned and any growing hair was removed to decrease the electrical resistance of the skin over the site of the electrode placement.
- Ultrasound was applied from the first day post injury and continued throughout the study at a frequency of three sessions per week for 5 weeks. Ultrasound was applied on the site of injury with frequency 1MHZ and intensity of 0.5 W/cm\(^2\) for 5 minutes.
MES was applied from the first day post operative and continued throughout the study at a frequency of 3 sessions per week. MES was applied transcutaneously.

- Micro-current electric stimulator, model: EMSI-4250 (made in Taiwan) was used for the treatment. The active electrode (cathode) (1.0 x 1.0 cm) was placed over the tendon injury site, while the inactive electrode (anode) was placed proximally on the thigh region of the same side, approximately 3 cm apart. Clip electrode were used.
- Intensity 100 micro ampere, frequency 10 Hz, duration 30 min, pulse width 50 ms, and constant mode of application was used in the study.
- Only one person was responsible to provide treatment for all animals, to standardize the handling process.

Wound size measurements:
By using clear and sterilized plastic sheet to measure the wound length x width x depth, to get the total wound size, Wound circumference had taken by multiplying length x width x depth of the skin wound of all groups (both study groups and control group). This procedure took place before starting the treatment protocol, immediately after the surgical procedure was performed, and it was repeated each session during the treatment period throughout the study.

RESULTS
The data presented in table (1) showed the mean and the standard deviation of the wound measurements of the area of tenotomized tendon of the study group which received low frequency ultrasound were lower than the control group which did not receive the ultrasound treatment. The wound size measurements every other day between low frequency ultrasound and control groups showed significant decrease in wound size till complete healing, where the mean size decreased from 0.2388 ± 0.08206 to 0.0. Application of ANOVA showed significant decrease of wound size, where F value was 0.503 and p value was (P ≤ 0.02) as shown in table (1 and 2). Application of post hoc test showed a significant decrease in wound size during all periods of measurements except the first period of measurement (before treatment).
Table (1): Wound size measurement through treatment periods between control group low ultrasound and Micro-current group (mean ± standard deviation).

<table>
<thead>
<tr>
<th>Times of measurements</th>
<th>Control Group X±SD</th>
<th>low ultrasound group X±SD</th>
<th>Micro-current group X±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>0.236±0.041</td>
<td>0.2388 ±0.08206</td>
<td>0.213±0.0612</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>0.177±0.034</td>
<td>0.1280* ±0.05098</td>
<td>0.148±0.026</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>0.146±0.033</td>
<td>0.0554* ±0.02984</td>
<td>0.064* ±0.0182</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>0.11±0.032</td>
<td>0.0213* ±0.0238</td>
<td>0.0386* ±0.0152</td>
</tr>
<tr>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>0.04±0.021</td>
<td>0.0*</td>
<td>0.0*</td>
</tr>
</tbody>
</table>

*significant at ≤ 0.05

Table (2) ANOVA between low frequency ultra sound and control

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Degree of freedom</th>
<th>F value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 2 Vs control</td>
<td>29</td>
<td>0.503</td>
<td>≤ 0.02</td>
</tr>
</tbody>
</table>

Table (3): Application of Analysis of Variance between Micro-current group during periods of measurements.

<table>
<thead>
<tr>
<th>Micro-current vs Control g</th>
<th>Degree of freedom</th>
<th>F value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>29</td>
<td>0.3571</td>
<td>0.7029</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>29</td>
<td>3.506</td>
<td>0.0443*</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>29</td>
<td>21.923</td>
<td>&lt; 0.0001*</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>29</td>
<td>0.5182</td>
<td>0.6014</td>
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<tr>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>29</td>
<td>33.058</td>
<td>&lt; 0.0001*</td>
</tr>
</tbody>
</table>

*significant <0.05

Comparing wound size in low frequency ultrasonic group among the times of measurements Vs the control has shown a significant decrease of wound size where the mean value decreased from 0.2 mm ± 0.03 to 0.0 mm in the fifth time of measurement while the wound size of the control group decreased from 0.2 mm ± 0.08 mm in the fifth time of measurement. The t test has shown significant decrease in wound size measurement where the t value and P value showed that it was significant during 3<sup>rd</sup> and 5<sup>th</sup> times of measurements as shown in table(4).
Table (4): t-test between low frequency ultrasonic group and Control group among evaluation periods

<table>
<thead>
<tr>
<th>low frequency ultrasonic vs Control g</th>
<th>Degree of freedom</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>9</td>
<td>0.6331</td>
<td>0.24520</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>9</td>
<td>3.531</td>
<td>0.5312</td>
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<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>9</td>
<td>6.000</td>
<td>&lt; 0.0001*</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>9</td>
<td>0.6432</td>
<td>0.2843</td>
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<tr>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>9</td>
<td>7.83</td>
<td>&lt; 0.0001*</td>
</tr>
</tbody>
</table>

Comparing wound size in Micro-current group among the times of measurements Vs the control has shown a significant decrease of wound size where the mean value decreased from 0.2 mm ± 0.06 to 0.0 mm in the fifth time of measurement while the wound size of the control group decreased from 0.2 mm ± 0.08 in the fifth time of measurement. The t test has shown significant decrease in wound size measurement where the t value and P value showed that it was significant during 2<sup>nd</sup>, 3<sup>rd</sup> and 5<sup>th</sup> times of measurements shown in table (4).

Table (4): t-test between Micro-current group and Control group among evaluation periods

<table>
<thead>
<tr>
<th>Micro-current vs Control g</th>
<th>Degree of freedom</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>9</td>
<td>0.8771</td>
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</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>9</td>
<td>2.631</td>
<td>0.0169*</td>
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<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>9</td>
<td>8.000</td>
<td>&lt; 0.0001*</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>9</td>
<td>0.7902</td>
<td>0.4397</td>
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<tr>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>9</td>
<td>10.83</td>
<td>&lt; 0.0001*</td>
</tr>
</tbody>
</table>

*significant at <0.05, t: test, p: probability.
Morphological changes:

Achilles tendon morphology:
The normal Achilles tendon of female rat which was not subjected to the experiment showed normal parallel arrangement of acidophilic collagen bundles separated by flattened Fibrocytes with dark flattened nuclei.

Group I (After one week):
One week following injury of Achilles tendon of untreated group (group I) revealed few collagen bundles arrangement with fibroblasts migrated to the area of injury with newly formed blood capillaries. In contrast, Achilles tendon of rats treated with low frequency ultrasound (group II), showed more abundant irregular arranged collagen bundles with numerous fusiform fibroblasts at the site of injury. Inflammatory cells and new blood vessels are also seen.

In cathodal treated achilles tendon of the same group, an apparent increase in the amount of regenerating collagen bundles was observed. Fibroblasts with pale oval nuclei and fibrocytes with dark flattened nuclei were aligned on the regenerating collagen bundles, infiltrating cells were scattered in-between the collagen bundles.

Two weeks following injury, the Achilles tendon in the untreated group (group II) showed collagen bundles invading the injured area with cellular infiltration and blood vessels. In contrast, rat Achilles tendon of (group II) treated with low frequency ultrasound showed denser collagenous bundles filling the injured area with areas of heavy cellular infiltration. Fig (1).

Fig (1): Photomicrograph of Achilles tendon of female rat in group II after two weeks showing condensed collagen bundles (arrow head) filling most of injured area with cellular infiltration. (H&E X100)

Two weeks following injury Cathodal treated achilles tendon of the same group showed regularly arranged regenerated acidophilic collagen fibers. Few Infiltrating cells were observed. Fig (2).

Fig.(2): Photomicrograph of a section in cathodal treated Achilles tendon in group III showing regularly regenerated acidophilic collagen bundles (arrow) (H & E, x100).

Five weeks following injury sections in Achilles tendon in untreated group (group I) showed collagen bundles (dense but in different directions), abundant fibroblasts with few fibrocytes, with also some blood vessels are still
seen. While group II showed parallel arrangement of the dense collagen bundles with less spacing and more fibrocytes. (Fig. 3).

**Fig (3):** Photomicrograph of Achilles tendon of female rat in group II treated with low frequency US for four weeks showing more regular arrangement of collagen bundles with less spacing. (masson’s X400).

Regularly arranged collagen bundles intermingled with many fibroblasts were recorded in group III. Regularly arranged collagen bundles occupied most of the field (Fig4).

**Fig. (4):** Photomicrograph of a section in cathodal treated Achilles tendon demonstrating regularly arranged collagen bundles occupying most of the field (arrow) (Masson’s Trichrome, x400).

**DISCUSSION**

The results of this study showed significant decrease of wound size among the low frequency ultrasonic and Microcurrent groups compared with the control group. Application of Bonferrini multiple trial test showed significant decrease in wound size during second, third, and fifth periods of measurements. Group (II): showed that wound size has shown a significant decrease from 0.2 mm ± 0.03 to 0.0 mm during three weeks where P value was < 0.0001. On the other hand, in the control group, the wound size decreased from 0.2 mm ± 0.08 where P value was < 0.0001 but this takes longer period than the experimental group.

Selection of ultrasound application parameters is based on the desired effect and the location and density of the tissue to be treated. These decisions are best made by the physician and the therapist experienced in performing therapeutic ultrasound. Common indications for high frequency ultrasound therapy include treatment of tendon injuries and short-term pain relief. Ultrasound has also been shown to promote healing of some acute bone fractures, venous and pressure ulcers, and surgical incisions. However, conventional therapeutic ultrasound can cause burns or endothelial damage if applied incorrectly.

Recently, low frequency ultrasound was tested and introduced to the market. The motivation of looking for alternative ultrasound parameters was due to the fact that application of high-frequency US in clinical medicine is limited due to tissue heating. Thus, using low-frequency US with less tissue heating, thereby acting as a "slow release" mechanism, may become the standard care in treating slow-to-heal lesions, skin ulcers and nonunion fractures. In addition it may be able to facilitate protein secretion and enzymatic reactions.
Based on the results of Marie et al., (2008) who reported that, low frequency ultrasound energy are thought to be primarily attributed to the mechanisms of cavitations and micro streaming. *Cavitations* involve the creation and oscillation of microscopic bubbles that concentrate acoustic energy into shearing and micro streaming fields. The movement and compression of these bubbles can cause changes in cellular activities\(^{17}\).

Furthermore, *Micro streaming* is the physical forces of sound waves that are capable of displacing ions and small molecules. The mechanical pressure applied by the micro streaming wave produces a unidirectional movement of fluid along and around cell membranes. Based on laboratory studies on both *vivo* and *vitro*, the combination of cavitations and micro streaming, which occur more frequently with low frequency ultrasound, appear to provide a mechanical energy capable of altering cell membrane activity and, therefore, cellular activity.

In contrast, Watson (2008) showed that enhancement of wound healing using the properties of high ultrasound suggested that the higher the US frequency, the greater the absorption rate; raising the temperature above normal thermal levels by a few degrees may be attributed to numbers of beneficial physiological effects\(^{8}\).

In this study, the wound size measurements were taken every other day for low frequency ultrasound and control groups. It showed significant decrease in wound size till complete healing, where the mean wound size decreased from 0.2388 mm ± 0.08206 to 0.0 (P value≤ 0.02), and application of post hoc test showed the significant decrease were in all times of measurement except the first period of measurement (before treatment).

One of the objectives of the use of therapeutic ultrasound in wound healing is to reduce the inflammatory phase and accelerate the migration and proliferation of fibroblasts, which are critical to the healing process. The results of this study went in accordance with several studies, that showed the same effect of low frequency ultrasound on the wound healing\(^{18,19,20}\).

Low-frequency ultrasound therapy is a modality used to promote healing in chronic wounds by cleansing and maintenance debridement to remove yellow slough, fibrin, tissue exudates, and bacteria. The mechanisms by which low frequency ultrasound energy stimulates wound healing have been previously described\(^{21}\).

Breuing et al., (2005) provided further support on the effectiveness of low frequency ultrasound therapy in a group of 17 patients with acute and chronic wounds of varying etiology. These patients also received adjunct wound therapy, which included moist dressings, alginate and Panafil. A total of nine wounds (47%) healed primarily or were sufficiently debrided to receive skin grafting, while six wounds (29%) achieved greater than 50% healing. The remaining 2 wounds achieved 20% and 30% healing of the original wound area. It should be noted that due to the varying etiology of wounds within this patient cohort, the frequency of treatment varied substantially, ranging from twice / week to fortnightly sessions and the average number of
treatments per wound ranged from 6 to 15 over the 3-month period\textsuperscript{(22)}. In this study, group(III): showed that wound size has shown a significant decrease from 0.2 mm ± 0.06 to 0.0 mm during two weeks where P value was < 0.0001. On the other hand, in the control group, the wound size decreased from 0.2 mm ± 0.08 mm where P value was < 0.0001 but this takes longer period than the experimental group. It was suggested that, electrode placement significantly affected field strength in the target tissue. Furthermore, the presence of many surrounding structures reduces field strength in the target tissue considerably. These factors should be taken into account when establishing protocols for electrical current based therapeutic devices once it has been proven that these devices are clinically effective. It was concluded that tissue composition and electrode placement of electrical therapeutic devices strongly affect the effective field strength in the target tissue. Knowledge about these effects were necessary for the further assessment of these devices with respect to their potential value for clinical use\textsuperscript{(23)}. There was another point with respect to the direction of current application. Physiological electric fields can also control the direction of cell migration \textsuperscript{(24)}. In general, cells orientated parallel to an electric field will retract, and reorient perpendicular to the electric field \textsuperscript{(25)}. After injury tenocyte proliferation and collagen synthesis were randomly organized, and may result in the formation of inferior tissue.

In an attempt to identify the optimal method for applying microcurrent in this study totenocytes in culture, the results revealed that the direct contact between the electrodes and the culture medium or the cells themselves resulted in extensive cell death. It was suggested that, this phenomenon could be a result of electrolysis, whereby dissolved positive and negative ions in the medium were discharged at the cathodal and anodal electrodes, respectively, and was probably mediated through formation of H\textsubscript{2}O\textsubscript{2} at the anodal electrode. The use of bridges to allow indirect current transmission avoided this. However, only the paper bridges worked satisfactorily. The agarose bridges most likely had an intrinsic resistance that was high enough to prevent sufficient current to generate a biological effect to pass to the cells\textsuperscript{(26)}. Similar results was reported by Mehmandoust at al., (2007)that, the use of positive polarity augments the migration and proliferation of epithelial cells and therefore hasten wound closing. It was suggested that, the wound closing in a shorter periods was due to the antibacterial effect of negative polarity and the epithelialization effect of positive polarity \textsuperscript{(27)}. Also Mehmandoust et al.,(2007)added that some useful effects of negative polarity include killing microorganisms, removing necrotic tissues due to decreasing pH of the wound environment, limiting protein molecule infiltration and therefore limiting the formation of edema in the injury site, and increasing fibroblast cell proliferation and collagen synthesis \textsuperscript{(27)}. This study was in agreement with Rowley et al., (1974) who study that the use of negative polarity for the first 3 days and positive polarity for the remaining days throughout the healing period. As
the negative polarity has antibacterial effects\(^{(28)}\). In contrast, Bayat et al., (2006) reported that, in both vivo and vitro studies the application of positive polarity has some useful effects, including destruction of microorganisms, increased migration and proliferation of the epithelial cells, increased attraction of macrophage cells to the wound site, and better stimulation of endogenous currents of the wound\(^{(29)}\).

It was known from the past that cathode was superior to anode in wound healing process. Robert I. and Pcker,\(^{(30)}\) reported that, the cathodal (negative) current has been shown to be successful in stimulating bone deposition and repair if applied at the fracture site as an indwelling electrode. Consistent with this empirically successful clinical approach to stimulating bone repair is the observation that injury to bone produces negative voltage-potential gradients in the area of injury relative to the undamaged bone. Short-lived potential differences are also induced by stressing the bone with a mechanical load. Areas of compressive stress are electronegative relative to the unloaded portion of the long bone. In addition PoltawskiL, and Watson T added that MES promotes healing in variety of bone and skin lesions. The evidence for other tissues is encouraging but presently scant. MES uses electric currents similar to those produced by the body during tissue healing. It may be particularly beneficial where endogenous healing has failed\(^{(31)}\).

The effect of the electrical stimulation on biological structures was related to the current flow through the target tissue. This study clearly demonstrates that the effective field strength in the target tissue may vary greatly with the plane in which the current is applied and with the tissues located between electrodes and target tissue. Main conclusion from this study is therefore that the current output of any therapeutic device has to be considered a very unreliable indicator of actual field strength in the target tissue, and hence of potential therapeutic effect. We did not vary the direction of the current, i.e. the positions of the negative and positive electrodes. To the authors’ knowledge there was no data on possible semi-conductivity of biological tissues, but it is an item that might be addressed in future studies\(^{(26)}\).

**Regarding the morphological changes**

Andres and Murrell 2008 reported that the healing process is a balance between the intrinsic and extrinsic healing processes. The mechanism for achieving this balance may lie in the differential ability of the cells to respond to local factors\(^{(7)}\).

In 2003 Joan and his colleagues reported that, the phases of wound healing are overlapping, but are described in a linear fashion for the purpose of clarity. They suggested that the five phases that characterize wound healing include (1) homeostasis, (2) inflammation, (3) cellular migration and proliferation, (4) protein synthesis and wound contraction, and (5) remodeling\(^{(32)}\).

In the present study, group (II) during the first two weeks post injury, the wound was heavily populated by inflammatory cells and vasculature; as the healing progressed fibroblasts and endothelial cells were predominated; mainly after the 3\(^{rd}\) week fibroblasts became inactive and...
changed into fibrocytes. After the 4th week fibrocytes predominated.

In the current study the morphometric results regarding the ratio between fibroblasts & fibrocytes showed significant increase in the numbers of fibroblasts which are responsible for collagen production and healing process in response to US in low subgroup when compared to both untreated and high subgroups after 1st two weeks of the study. This is in accordance with previous work of Yeung et al., 2006 who found an improvement in the quantity of fibroblasts and collagen alignment in Achilles tendons of rats treated with low ultrasound after the 3rd week of this study there was significant increase in the fibrocytes numbers in low subgroup when compared to both untreated and high subgroups (33).

In group, (III) (Two weeks following injury), H&E stained sections showed that collagen bundles were disrupted, irregularly arranged and infiltrated with active fibroblasts that exhibited pale oval nuclei. Mononuclear cell infiltration was clearly evident in between the bundles together with congested capillaries, these changes were gradually replaced by acidophilic regularly arranged collagen bundles that occupied most of the field. Resident and quiescent fibrocytes with dark flattened nuclei were aligned in-between these bundles and with gradual disappearance of the inflammatory cells and congestion.

Fereshte, 2007 added that the negative polarity (cathode) exhibited other useful effects in means of killing microorganisms, removing necrotic tissues due to decreasing pH of the wound environment, limiting protein molecule infiltration and therefore limiting formation of edema in the injury site and increasing fibroblast cell proliferation and collagen synthesis (34).

Going along with results of the present study, it was reported by Sharifi et al., 2007 that increased blood supply enhanced the rate of protein synthesis in fibroblasts responsible for collagen production, therefore, an adequate blood supply is necessary for tendon healing (16).

CONCLUSION

Both low frequency ultrasonic and microcurrent electrical stimulation is an effective mean for promoting wound healing. Despite many studies on wound healing, the electrical stimulation is still in its infancy, an important parameter of electrical stimulation in wound healing is the type of applied polarity. The present study revealed the following findings, that "low frequency ultrasonic has more significant effect than microcurrent on decreasing wound size after tendon suture".

REFERENCES


after immobilization and remobilization.
4. Tallon C, Maffulli N, Ewen SW.: Ruptured
Achilles tendons are significantly more
degenerated than tendinopathic tendons.
ClinOethopRelat Res.2006;443:320-32
evaluation of He-Ne laser photostimulation
in healing Achilles tendon. Laser Med
7. Andres BM, and Murell GA.: Tendon:
biology, biomechanics, repair, growth
factors, and evolving treatment options. J
8. Watson,T. : "Ultrasound in contemporary
physiotherapy practice."Ultrasoundics.
on healing tissues." Journal of Hand
11. Watson, T. and S. Young:.Therapeutic
Ultrasound.Electrotherapy : Evidence
Based Practice. T. Watson. Edinburgh,
Robinson, P. S.; Beason, D. P.; Carine, E.
T.; Soslofsky, L. J.; Iozzo, R. V.; Birk, D.
E., : "Decorin regulates assembly of
collagen fibrils and acquisition of
biomechanical properties during tendon
development.". Journal of Cellular
doi:10.1002/jcb.20776. PMID 16518859.
13. Warden, S. J. : "Low-Intensity Pulsed
Ultrasound Accelerates and a Nonsteroidal
Anti-inflammatory Drug Delays Knee
14. Picker RI. : Low-volt pulsed microamp
15. Poltawski L, and Watson T. :Bioelectricity
and microcurrent therapy for tissue healing – a narrative review. Physical Therapy
Reviews.:2009; 14(2):104-114
16. Sharifi,D., Sasani,S., Hamidzadeh, M.
R.,Mohitmafi,S.: Effects of transcutaneous
electrical stimulation on the healing of
surgically severed Achilles tendon in
17. Marie G, Julien G, Alain M: Time of day
effect on the torque and neuromuscular
properties of dominant and non dominant
quadriceps femoris. Chronobiology
18. Johns L.:Nonthermal Effects of
Therapeutic Ultrasound: The Frequency
Resonance Hypothesis. J Athl Train. Jul-
19. O'Brien ,WD, Jr.. Ultrasound-biophysics
mechanisms. ProgBiophysMolBiol
Jan;2007;93(1-3):212-55.
20. ter HG.:Ultrasound bioeffects and
safety. ProcInstMechEng H 2010;
224(2):363-73.


Lower-Limb Muscular Strength, Balance, and Mobility Levels in Adults Following Severe Thermal Burn Injuries

Mohammed T. A. Omar, PhD, PT,* Amal M. Abd El Baky, PhD, PT,*† Anwar A. Ebid, PhD, PT*

Severe burn injuries are associated with hypermetabolic response and increased catabolism. These lead to a vast loss of muscle mass and reduced muscle strength and function. Therefore, the aim of this study is to determine the impact of severe burn injuries on lower-limb muscular strength, balance, and mobility level in adults. Forty burned adults with burned TBSA (burned TBSA) ≥40% participated in this study. The peak torque and total work of quadriceps and knee flexors were calculated at 150°/sec using Biodex isokinetic dynamometer. Balance and mobility were tested via the Biodex balance device and the high mobility assessment tool, respectively. Twenty-three matched nonburned healthy adults were evaluated and served as a control group. Severely burned adults exhibited significantly lower peak torque and total work in their quadriceps (27.50 and 22.58%, P < .05) and knee flexors (23.72, and 21.65%, P < .05) relative to the nonburned adults. Burned adults had a significant decrease in stability index and balance including the dynamic limits of stability (P < .05). The high mobility assessment tool scores were significantly lower (42 ± 7.64, P < .05) when compared with control subjects (51 ± 1.62). Patients who had severe burns (burned TBSA ≥ 40%) showed muscular weakness, limited balance, and mobility levels between 16 and 24 weeks after discharge from the hospital compared with matched nonburned control subjects. These results can guide therapists in creating rehabilitation programs that focus on the specific difficulties faced by burned patients. (J Burn Care Res 2017;XXX:00–00)

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Severe burn injuries are associated with hypermetabolic response and increased catabolism. These lead to a vast loss of muscle mass, reduced muscle strength and endurance, limited walking ability, and reduced functional mobility.1−7 These are worsened by deconditioning (e.g., prolonged bed rest, immobilization, and inactivity).5 Previous studies have suggested that sensory neurons impeded in dermal tissue are damaged secondary to burn injuries resulting in impaired perception and postural imbalance.8−11 These will influence the ability to execute a range of activities and function in both the short and long term.

Persistence of muscle weakness is well known in both adults6,12 and children who sustained injury and had more than 30% of burned TBSA (burned TBSA).13,14 However, there are limited studies on the use of the isokinetic dynamometer to quantify recovery of muscle strength following burn injury.6,12−19 In addition, the use of the Biodex balance system has not yet been described in the literature, and only a few studies have tested walking and mobility levels following burn injury.12,16,20−24 Therefore, this study determined the impact of thermal burn injuries on the lower-limb muscular strength, balance, and functional mobility in adults and compared results with norm values of a matched nonburned group.

METHODS

Burned Participants

This is a cross-sectional descriptive study, which was approved by the postgraduate institutional ethical committee at Faculty of Physical Therapy. Burned
adults (men and women) were recruited from OM El-Masriien Hospital, Giza, Egypt. The participants with following criteria were enrolled in this study: 1) Aged 18 to 35 years; 2) sustained second to third degrees burns to the dominant or both lower extremities; 3) burned TBSA ≥ 40% as estimated by the rule of nine; 4) completion of skin grafting at least 3 months at the time of assessment. The exclusion criteria were existing leg amputation, psychiatric, neurological, and cognitive disorders. All participants received similar standard medical care and rehabilitation services from the time of emergency admission throughout discharge.

Nonburned Group
Based on the previous study of St-Pierre et al,6 and Grisbrook et al,25 the burned participants were matched to nonburned control healthy adults who were voluntarily recruited from the community through personal contact according to sex, age, weight, height, body mass index, and level of physical activity. Participants in both groups were sedentary (not involved in regular physical activity, defined as 1 hour of moderate intensity exercise that performed three times per week) in the past 3 months. They did not engage in any rehabilitation program and/or use medications that may affect muscle strength.

Data Collection Procedures
The assessment procedures and data collection were performed in the Biodex lab at the Faculty of Physical Therapy, Cairo University, Giza, Egypt. Outcomes included muscle strength, balance, and mobility level. These outcomes were measured between 16 and 24 weeks after discharge from the hospital. On the first visit, the therapist provided the participant a brief description of the testing procedures. Demographic data (eg, age, sex, weight, and body mass index) and medical data (eg, extent of burn, location of burns, skin grafting, length of hospital stay, duration since discharge) were collected for all participants. All participants signed an informed consent form before engaging in the study.

Isokinetic Muscle Strength Assessment
A Biodex isokinetic dynamometer (Biodex Medical System, Shirley, NY, linked to IBM PC computer software) was used to measure the muscular strength after calibration according to the manufacturer’s instructions. A therapist reported the values of knee flexors and quadriceps muscle strength of dominant leg regardless the location of burns at an angular velocity of 150°/sec.12,15,16 The details of the protocol and test procedures were described in our previous study.12,15,16 Values of peak torque (PT) and total work (TW) were calculated using the Biodex software system.

Balance Assessment
A Biodex Balance System (Biodex Medical Systems, Shirley, NY) consists of movable balance platform that provides 20° surface tilt through 360° range of motion. The platform interfaces with computer software that enables the device to serve as an objective assessment of balance. Before the start of each testing session, the Biodex was calibrated according to the manufacturer’s manual. The participants were familiarized with testing procedures through free practical sessions to minimize the learning effects that occur during testing. All measurements were performed at level eight of stability (the most suitable level), and the test duration was set at 20 seconds for three successive trials. Each participant was tested for stability index (SI) and limits of stability (LOS). The LOS is defined as the area that the subject safely moves without changing the base of support. The SI represents the patient’s ability to control balance and motor control skills at 50% LOS.26–29

To test SI, the participants were asked to step on the platform and instructed to grasp the support handles at the beginning and then release them as the test proceeded with open eyes and barefoot. Then, the participants were informed to assume the proper centered position as soon as the platform was released by shifting the foot position on the platform, and the foot position was recorded by using coordinates on the platform’s grid.26–29

The LOS test prompted participants to move a cursor, viewed on the visual feedback screen by leaning toward a target while standing on the fully unstable platform to keep the cursor at the center of the screen grid. The LOS test measures the time and accuracy with which participants transferred their estimated center of gravity while moving the cursor to intercept each of eight successive targets on the display screen. The targets were positioned at 45° intervals around a central target that represented the participant’s center of pressure under static conditions. Each target was randomly highlighted, and the participant reached the target by leaning and returning to the center position before the next target was selected and displayed on the screen. The test was completed when all eight targets had been reached. Target placement was preset by the manufacturer at 50% of the LOS. The system calculated balance indices including the SI and the LOS scores. These were collected and used for further analysis.26–29
Mobility Assessment

The high mobility assessment tool (HiMAT) is a valid unidimensional assessment tool developed to examine high-level mobility function in a population with traumatic brain injury. The HiMAT can be used for mobility assessment following burn injuries.

The HiMAT includes 13 items that assess a range of high-level activities including walking tasks (eg, walking, walking backwards, walking on toes, and walking over an obstacle), running, skipping, hopping forward, bounding, and going up and down stairs. Each item is scored on a scale 0 to 4, where zero represents the inability to perform an item, and four represents increasing levels of ability (based on the time/distance they receive). All items are summed for a total score of 54. Higher scores show a higher level of performance. Norms for healthy adults aged 18 to 25 were obtained from the control healthy subjects.

RESULTS

Participant Characteristics

Table 1 summarizes the demographic characteristics of both groups. Forty burned adults (26 males and 14 females) and 22 matched, nonburned healthy adults (13 males and 10 females) were involved in this study. No significant differences were observed between groups with regard to age (P = .75), weight (P = .11), height (P = .91), BMI (P = .17), and distribution of sex (P = .33). The mean extent of the burned TBSA was 45.02% (range 40 to 55%). The extent of full-thickness burned TBSA was 18.50% (range 15 to 25%). The average extent of burns to lower limb burned TBSA was 18% (range 15 to 27%). All the burned participants had burns to their lower limbs. Eighteen of the participants also had bilateral upper limb burns; five also had injuries to the face. Forty participants had skin grafting surgery during hospitalization, partial thickness skin grafts (n = 10), and full-thickness skin grafts (n = 5) in their dominant lower limb. None of the subjects had surgeries for at least 3 months before assessments. The mean length of stay was 76.75 ± 16.21 days (range 42 to 98 days), and 52.50% (21 participants) were discharged within 11 weeks of the burn.

Muscle Strength

Table 2 reports the mean values of PT and TW for the participants’ quadriceps and knee flexors. The PTs for quadriceps and knee flexors significantly differed (P = .03) in the burned participants (62.89 ± 7.38 and 57.17 ± 5.87 Nm), relative to the nonburned group.

Data presented as mean ± SD, or number, and range as in bracket, no significant (P > .05) differences between groups.

BMI, body mass index; LL, lower limb; N/A, nonavailable; UL, upper limb.
The TW performed for quadriceps and knee flexors were significantly ($P = .03$) decreased in burned participants (57.37 ± 5.62 and 49.05 ± 5.28 J) vs the nonburned group (73.63 ± 10.37 and 62.61 ± 5.56 J). The burned participants exhibited significantly ($P = .02$) lower PT in the quadriceps (27.50%) and knee flexors (23.72%) and produced less ($P = .02$) TW in the quadriceps (22.58%) and knee flexors (21.65%) compared with the nonburned group. In general, the individual mean $Z$ score for PT and TW for both quadriceps and knee flexors was significantly lower ($P < .05$) in all burned participants vs the nonburned group.

**Balance Assessment**

Table 3 reports the mean values of the SI and dynamic LOS. There was a significant difference ($P = .02$) in SI between the burned participants (4.42 ± 0.35) and the nonburned group (1.92 ± 0.50). The dynamic LOS showed significant differences ($P = .03$) between the burned participants (15.50 ± 2.30) when compared with the nonburned group (21.22 ± 3.62).

**Table 3.** Mean values of SI and total dynamic LOS in both burned and matched control groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Burned Group (n = 40)</th>
<th>Control Group (n = 23)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td></td>
<td>SI</td>
<td>LOS</td>
</tr>
<tr>
<td></td>
<td>4.42 ± 0.35*</td>
<td>1.92 ± 0.50</td>
</tr>
<tr>
<td></td>
<td>15.50 ± 2.30*</td>
<td>21.22 ± 3.62</td>
</tr>
</tbody>
</table>

*Significant ($P < .05$) decrease compared with control group.

LOS, dynamic limit of stability; SI, stability index.

These differences demonstrated lower balance ability in patients with severe burn injuries. In total, all burned participants had significantly lower $Z$ scores. There was also a significant deviation from the norm in the group mean for SI and LOS.

**High Mobility Assessment Tool**

The total HiMAT score and all subscores for the burned and nonburned groups are presented in Table 4. The mean total HiMAT score in the burned adults was $42.76 ± 7.64$ compared with $51.0 ± 1.62$ in the nonburned group ($P = .01$). Eight of the 13 mobility task scores differed significantly from the nonburned group: “walking backwards,” “running,” “hop forward,” “bound affected leg,” and “four-stair activities.” Five males had a normal average total HiMAT score, whereas 35 participants scored lower than normal (14 females and 21 males) in the burned group. The HiMAT scores were lower in females than males in the burned (39.19 ± 5.7 and 46.00 ± 7.84, $P = .03$) and nonburned (52.07 ± 1.49 and 49.70 ± 1.05, $P = .01$) groups. The Mann–Whitney $U$ test showed a significant ($P = .03$) difference between sex distributions in total HiMAT scores between the two groups.

**Source of Variation in the Strength Measures**

For the burned group, significant correlations were observed between burned TBSA with muscular strength ($r = .40$, $P = .01$) and mobility level on HiMAT ($r = .30$, $P = .03$). Moreover, there was a

**Table 4.** Total HiMAT score and item scores in the burned group compared with matched control group.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Burned Group (n = 40)</th>
<th>Control Group (n = 23)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>Walk</td>
<td>4 ± 0.60</td>
<td>4 ± 0.30</td>
</tr>
<tr>
<td>Walk backwards</td>
<td>3 ± 0.51*</td>
<td>4 ± 0.20</td>
</tr>
<tr>
<td>Walk on toes</td>
<td>3 ± 0.70</td>
<td>3 ± 0.31</td>
</tr>
<tr>
<td>Walk over obstacle</td>
<td>3 ± 0.70</td>
<td>3 ± 0.20</td>
</tr>
<tr>
<td>Run</td>
<td>2 ± 1.20*</td>
<td>3 ± 0.70</td>
</tr>
<tr>
<td>Skip</td>
<td>3 ± 1.81</td>
<td>3 ± 0.61</td>
</tr>
<tr>
<td>Hop forward</td>
<td>3 ± 1.31*</td>
<td>4 ± 0.51</td>
</tr>
<tr>
<td>Bound (affected)</td>
<td>3 ± 1.21*</td>
<td>4 ± 0.60</td>
</tr>
<tr>
<td>Bound (less affected)</td>
<td>3 ± 1.20*</td>
<td>4 ± 0.60</td>
</tr>
<tr>
<td>Up stair dependent</td>
<td>4 ± 0.80*</td>
<td>5 ± 0.31</td>
</tr>
<tr>
<td>Up stair independent</td>
<td>3 ± 0.70*</td>
<td>4 ± 0.21</td>
</tr>
<tr>
<td>Down stair dependent</td>
<td>4 ± 0.61</td>
<td>5 ± 0.30</td>
</tr>
<tr>
<td>Down stair independent</td>
<td>3 ± 0.81*</td>
<td>4 ± 0.20</td>
</tr>
<tr>
<td>Total score of HiMAT</td>
<td>42 ± 7.64</td>
<td>51 ± 1.62</td>
</tr>
</tbody>
</table>

*Significant ($P < .05$) decrease compared with control group.

HiMAT, high mobility assessment tool.
trend indicating an effect of the extent of burn on muscular strength and mobility level. There was no significant relationship between length of time since discharge and muscular strength, mobility level, and balance indices.

**DISCUSSION**

The current study indicates a significant decrease in the amount of PT and TW generated by quadriceps and knee flexors in our burn patients. Furthermore, a significant loss of balance and high-level mobility problems were presented in adults with burned TBSA ≥ 40% relative to the nonburned group.

Regarding muscle strength, our findings agreed with our earlier study. The PT of the knee extensors and flexors in the burned group were significantly lower (28 and 24%, respectively) when compared with the nonburned adult. Moreover, the PT of knee extensor demonstrated a 30% decrease in the burned group vs the nonburned group. Recent study by Ebíd and Elsdén concluded that the PTs of eccentric, concentric, and isometric muscles contraction increased by 24.50, 32.48, and 52.38% in nonburned subjects when compared with burned adults at 12 weeks post burn. Moreover, the findings of the current study are consistent with previous results that demonstrated persistence muscular weakness in burned adult (TBSA > 35%) and children (TBSA; 18–42%). In contrast to our findings, Grisbrook et al and Desselbrooke et al failed to show a significant difference in muscle strength between burned and nonburned subjects.

This inconsistency across the literatures might be related to the variability in the population (adults vs children), evaluation time post burn injury (range 4–40 months), discrepancies in average percentage of TBSA (18–42%), and sample size. Finally, muscle strength was tested using isokinetic at different angular velocities (60 and 150°/sec), different instruments (isokinetic vs hand-held dynamometer), and different muscles groups (knee extensors and flexors, elbow flexors and extensors, back muscles, and handgrip strength).

The decrease in muscle strength might be attributed to deconditioning after burn injury and insufficient rehabilitation. In addition, severe burns can lead to a change in metabolism that might persist up to 24 months after the initial injury. These cause significant muscle wasting and deconditioning. Recent studies suggested that burn has a direct impact on the mitochondrial function and gene expression of skeletal muscles in a nonburned limb. However, a complete understanding of these processes is still lacking.

In this study, we used isokinetic testing to assess muscle function. Isokinetic testing also allows measurement of dynamic muscular parameters under a predetermined rate. The rate chosen for this experiment was 150°/sec, which approximates the motion of walking activities. For practicality, we chose this value because rehabilitation programs should focus on helping the patient to resume normal walking and daily living activities or goal-oriented tasks—these are dynamic muscular functions.

To the best of our knowledge, the current study is the first to use Biodex balance in burned participants, and the results should encourage further development of using balance assessment. Our findings of reduced balance indices in adult participants with severe burns are consistent with existing literature. However, previous studies used other outcome measures for balance assessment such as the Berg Balance Scale, single leg stance, time-up-and-go test, and tandem walk test. These results agreed with findings of Schneider et al, who reported lower scores (26–medium risk of fall) on Berg Balance Scales in the burned group on admission.

The defect in balance following burn injuries might contribute to multiple factors such as loss of tactile sensation, proprioception, and muscle strength, as well as limited joint mobility and cognition. All are potentially affected in severe burn injury. Balance can further worsen due to burn complications including prolonged hospitalization, poor nutrition, pain, and neuropathies. In addition, Nedelec et al and Malenfant et al reported that burn injury affects dermal tissue that contains sensory neurons. These neurons send conscious and automatic feedback, which controls balance and coordination.

The current study used the HiMAT to assess mobility level. Our findings of mobility problems in adults with severe burns are consistent with the literature. In our study, the burn-injured participant displayed decreased mobility activities (42/54) relative to the nonburned group (51/54). Some tasks did not reach full functional capacity such as hopping, skipping, and running, walking on toes, walking backwards, and walking over an obstacle. These results agreed with findings of Grisbrook et al, where the authors showed a significant decrease in the total HiMAT score in burned injury subjects vs a nonburned group.

Recently, Ebíd and Elsdén found that ambulation speed differed markedly between burned subjects (mean = 2.80 seconds) compared with age-matched healthy subjects (mean = 4.30 seconds). Data from
our previous study showed a significant decrease in walking speed on the treadmill in burn-injured participants (72.60 m/min) 6 m/min compared with age-matched health subjects (99.70 m/min) 7 m/m/ after 6-month post burn in the adult with TBSA ≥ 40%.12,16 Despite these similarities between our results and the existing literature, the previous studies used other outcome measures for mobility assessment, such as walking speed and distance.12,15 and three-dimensional motion analysis.23 Only female participants (n = 9) were tested with variation in assessment time from 1 to 12 weeks following burn injury in the study conducted by Grisbrook et al.25

There was a lack of information in the literature regarding assessment of muscle function by an objective and reliable method. Furthermore, there were only a few trials that described mobility level following burn injuries, and no study described the effect of burn on balance. We thought our study results would share in documenting data in this field. Moreover, it has potential clinical importance in the field of burn rehabilitation because this information can evaluate and compare muscle function, balance, and mobility of burned patients to nonburned individuals. Moreover, it can help in planning a rehabilitation protocol.

Furthermore, we used two different strategies to control for possible confounding factors in this study: matching and logistic regression analysis. Controls were matched on age, sex, BMI, and physical activity. Thus, these variables should not be confounding factors. Furthermore, age ranged from 18 to 35 years in all groups. This is a relatively narrow range, and age-related differences regarding muscular strength, balance, and mobility outcome within this range are unlikely. This further suggests that age is unlikely to be a confounding factor. Sex distribution was matched between burned and nonburned subjects. However, sex distribution differed within the burned group (26 M/14 F). This may have influenced the comparison on the raw scores and total mean scores because the normative values are sex specific.

The current study had several limitations including the small sample size and local burn site recruitment. These limit generalization. Therefore, large sample size associate with multiple sites recruitments are recommended. Location of burn (eg, traversing the joint, near to joint or away from joint) may affect the results in a disproportionate manner. Therefore, additional studies are required to investigate all these factors. Normalizing data by lean body mass can facilitate data interpretation. However, in our study, mean values of PT were not corrected by lean body mass. Therefore, further study should use lean body mass of leg muscles as a correction factor for the observed values of PT and TW. However, the effects of lean body mass may be secondary to changes in neuromuscular efficiency, fiber recruitment, or intrinsic contractile characteristics of muscle. Normative values of undefined population were used as reference standards to compare our findings. However, these studies were from different countries, and involved participants of different ages, sex, and ethnicities. Discrepancies in assessment and follow-up times were reported between studies.13,14,17–19,23,25,33

**CONCLUSION**

Muscular strength, balance, and mobility are determinately affected by severe burn injuries. Because functional outcomes are the prime focus in burn rehabilitation, the current study used objective measures that provide a more detailed assessment of muscle strength, balance, and mobility in a severely burned adult population. Therefore, these results can guide therapists in creating rehabilitation programs that focus on the specific difficulties faced by each patient.

**REFERENCES**


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PHYSICAL THERAPY PROFESSION PERCEPTION BY PHYSICIANS AND MEDICAL STUDENTS IN SUDAYR REGION

Amal Mohamed Abd El Baky

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ABSTRACT

Background: Physiotherapy has been defined as a dynamic health care profession with established theoretical and widespread clinical applications in the preservation, development and restoration of optimal physical functions. While physical therapist is a member of primary care team. He has an important role in improving public health and meeting national targets. Physical therapy mainly depends on referrals from physicians of different fields of medicine so poor knowledge about physical therapy profession may lead to misconceptions about the profession and inter-professional conflicts.

Subjects: 150 persons “physicians of many facilities in Sudayr region and medical students from the faculty of medicine at Al Majmaah University” participated in this study. Methods: A survey would be done about physical therapy profession from views of physicians and medical students. A self-developed closed –ended questionnaire was designed. The questionnaire included informations on participants’ demographic data, perception of physical therapy subspecialties, roles, and modalities.

Objectives: The aims of this study were mainly to clarify the importance of physical therapy profession and to highlight the role of physiotherapist as a member of medical team.

Results: The results revealed that there was high awareness about physical therapy (PT) subspecialty regarding orthopedics with a percentage of 95.3% as well as to exercises as one of physical therapy modality with a percentage of 95.3%. In contrast it showed lack of awareness regarding the PT modality as hydrotherapy with a percentage of 56%.

Conclusion: The study concluded that there is deficits in the perception in different areas regarding to PT profession. This lack of awareness must be overcome.

KEYWORDS: Physical therapy; Role of physiotherapy; PT modalities; PT perception

INTRODUCTION

Physiotherapy (PT) is defined by the World Confederation of Physical Therapy (WCPT) as “services to people and populations to develop, maintain and restore maximum movement and functional ability throughout the life span” 1. It also commonly known as physical therapy. While physiotherapist (also physical therapist) is a member of primary care team2. 3.

The physical therapy service gained its importance in developed nations which is offered through primary health centers and funded by the public health system after having understood the need of this service in prevention, promotion, curative and rehabilitation of health for the individual and population. Hence the profession has a good development and the scope is growing each year, but, there is not equal importance given to physical therapy service and its profession in developing world4.

As a result of increasing incidence of disability and deficits resulting from traffic accidents, the demand to medical rehabilitation is increasing. For this reason the government of the Kingdom of Saudi Arabia represented by the Ministry of Health is interested in providing rehabilitation services to rehabilitate these cases through providing hospitals, rehabilitation centers and medical departments in all regions of the Kingdom5.

Physicians have profound influence on other health professions including physiotherapy as they are at the ‘top of the pyramid’ of health care professionals6. Generally, patients still rely on physicians for recommendation to other health care professionals. Medical referrals serve not only as a tool for communication, but as an indicator of the level of awareness of physiotherapy by referring health care professionals7. As well as undergraduate medical students represent a key target because they are the future physicians. Also, students have been found to be socially representative of the general population in their assessments8.

According to Jackson (2004)9, lack of knowledge about a profession may lead to misconceptions about the profession and inter-professional conflicts. Thus, understanding of physicians’ and medical students’ perception of PT profession would help the medical team to provide better health care services.

OBJECTIVES

The objectives of this research are to: clarify the importance of physical therapy profession and highlight the role of
physiotherapist as a member of medical team, explore the perceptions, views of physician and medical students about the physiotherapy profession, identify areas of deficit in physicians' and medical students' perception of PT profession in Sudbury region, and update the knowledge of public about physiotherapy profession to benefit the health care process.

REVIEW OF LITERATURE

A profession is a vocation obtained through education in a college or university which gives identification, shares common values and duties for public good by also having responsibility for knowledge development and research. While professionals are the people who practice specialized knowledge in the field for a fee. In addition health professionals are the one who deliver health care service through preventive, promotive, curative and rehabilitative activities for individuals and community. PT is considered as one of health care profession carried out by physiotherapists whom through their examination, evaluation, and physical intervention skills works on healing of impairments and disabilities and also helps in promoting ambulation, functional abilities, quality of life and movement. However, one of the major objectives that should not be ignored by physical therapy profession is to "promote the health and well-being of people with disabilities". PT involves the interaction between the physical therapist, patients/clients, other health professionals, families, care givers and communities in a process where movement potential is assessed and goals are agreed upon, using knowledge and skills unique to physical therapists. Physiotherapists often mainly depend on referrals from physicians from the different fields of practice of medicine. Since a high standard of patient care is the goal of the medical team, so effective communication between the physician and the physical therapist is necessary to ensure this level of care.

The extensive knowledge in physiotherapy and the broad scope of physiotherapy paved the way of much specialization within the physiotherapy profession. The specializations which are registered in American Board of Physiotherapy that list eight specialist certifications, which are (1) cardiovascular/pulmonary physical therapists who treat a wide variety of individuals with cardiopulmonary disorders or those who have had cardiac or pulmonary surgery, (2) clinical electrophysiology is a specialty area which encompasses electrotherapy, electrophysiological evaluation, physical agents, and wound management, (3) geriatric physiotherapist covers a wide area of issues concerning people as they go through normal aging as; arthritis, balance disorders, etc., (4) neurological physical therapy is a field focused on working with individuals who have a neurological disorder or disease as Parkinson's disease, spinal cord injury, and stroke, (5) orthopedic physical therapists diagnose, manage, and treat disorders and injuries of the musculoskeletal system including rehabilitation after orthopedic surgery, (6) pediatric physiotherapist assists in early detection of health problems and uses a wide variety of modalities to treat disorders in the pediatric population, (7) sports physical therapists are involved in the care of athletes from recreational to professional and Olympians. This area of practice includes athletic injury management, including acute care, treatment and rehabilitation, prevention, and education, and (8) women's health PT addresses women's issues related to child birth, and post-partum. These conditions include lymphedema, osteoporosis, pelvic pain, prenatal and post-partum periods, and urinary incontinence.

There are wide variety of interventions in physiotherapy they are: therapeutic exercises, which are planned physical movements, postures and activities to prevent impairments, promote function, reduce risk, optimize overall health and improve fitness and well-being, electrotherapy; it is using the electrical energy for treatment of medical conditions, airway clearance techniques, which involves clearing the airway for an improved breathing using different techniques like postural drainage, deep breathing exercises, spinal mobilization, vigorous chest massage, suctioning, positioning etc., manual therapy techniques; these are hands on techniques like manipulation and mobilization for assessment and treatment of joint structure and soft tissues, physical agents and mechanical modalities; physical agents are different forms of energy and materials used for therapeutic purpose by applying over the body and they include heat and cold while mechanical modalities are used to apply mechanical force which can increase or decrease pressure in the body, prescription and application of mobility aids like wheel chair, crutches, canes, walker and assistive devices like orthotics and prosthetics, and therapeutic massage; that provides pain relief to soft tissues, decrease muscle tone, improve lymphatic drainage and induce relaxation (physical & mental) to the body.

MATERIALS AND METHODS

Study Design: Cross-sectional study was approved by the Research Ethical Committee of Basic and Health Science Research Centre.
"BHSRC", Majmaah University, Kingdom of Saudi Arabia.

Subjects: A sample of 150 persons (73.3% male and 26.7% female) was participated in this study. It consisted of 110 physicians from different specialties who are practicing in various facilities in Sudair region in addition to 40 medical students from faculty of medicine-Majmaah University. Table 1 showed the demographic data of the sample.

Questionnaire Design: A self-developed questionnaire was used to explore the perceptions and views of physician and medical students about the physiotherapy profession. In order to ascertain content validity, two copies of the initial draft of the questionnaire sent to two physiotherapy educators from the College of Applied Medical Sciences. Pilot tested of the questionnaire was conducted on 10 practicing physicians to ensure that the questions are clearly stated and easily be understood by the respondents.

The questionnaire consisted of 3 sections; section A: included collected information on personal characteristics such as: age, sex, nationality, specialty and city, section B: included collected information on educational attainment, university of graduation, year of graduation, working relationship with physiotherapists, rate of referral for physiotherapy, section C: included information about the perception of physical therapy subspecialties, modalities, physical therapy role, sources of information concerning physical therapy profession, and the extent of importance of physical therapy role as a member of medical team, and section D: for other suggestions.

The aims of the study would be clearly stated in a cover letter was attached to each copy of the questionnaire to clarify the importance of the study.

Procedures: A total number of 200 questionnaires distributed from October 1st to 30th 2013, to the physician and medical student in Sudair region. The participants were given 10 minutes to review the survey for any queries or required explanation, and they were given a one week to complete the survey.

Data Analysis: Data were analyzed using SPSS statistical software, version 20. Descriptive statistics were done to determine response frequencies and percentages.

RESULTS

Of the total 200 questionnaires distributed, 150 questionnaires were returned.

Demographics

Analysis of demographic data revealed that the majority of the respondents for this study were male with a percentage of 73.3% and 26.7% of this percentage were students from the faculty of medicine Majmaah University. The participants age percentages were 32% from 20-30 y, 28% from 30-40 y, 30% from 40-50y and 10% above 50y. It also showed that internal medicine specialty is the major specialty with a percentage of 13.3% and then orthopedic and pediatric with 10.7% and 8.7 respectively. (Table 1)

<table>
<thead>
<tr>
<th>TABLE 1. SUMMARY OF DEMOGRAPHIC DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
</tr>
<tr>
<td>--------------------------------------</td>
</tr>
<tr>
<td>Sex</td>
</tr>
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<tr>
<td>Female</td>
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<tr>
<td>Age (y)</td>
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<td>30-40</td>
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<td>Specialty of physician:</td>
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<td>Neurology</td>
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<td>Internal medicine</td>
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<tr>
<td>Obstetrics and gynecology</td>
</tr>
<tr>
<td>Community medicine (PT subspecialty)</td>
</tr>
<tr>
<td>Surgery</td>
</tr>
<tr>
<td>Others</td>
</tr>
</tbody>
</table>

Results of the first question "which of these subspecialty are considered to be related to physiotherapy?"

Table 2 showed that the highest percentage of awareness of PT subspecialty were orthopedic, neurology and internal medicine with a percentage of 95.3%, 82% and 68% respectively, while the lowest awareness were obstetrics & gynecology, pediatrics and burns with a percentage of 66%, 63.7% and 56.7% respectively.

Results of the second question "which of the following is considered as PT modality?"

As revealed in fig 2 about 95.3% of the total sample was aware of exercises as a PT modality. Respondent perception of manual therapy, massage and electrotherapy were 87.3%, 82% and 71.3% respectively. In addition it showed that the lowest awareness of PT modalities were traction and hydrotherapy with a percentage of 56.7% and 56% respectively.
### TABLE 2. THE FREQUENCIES AND PERCENTAGES OF PHYSICAL THERAPY SUBSPECIALTY AWARENESS

<table>
<thead>
<tr>
<th>PT subspecialty</th>
<th>SR N(%)</th>
<th>R N(%)</th>
<th>UC N(%)</th>
<th>U N(%)</th>
<th>SU N(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthopedics</td>
<td>77.3%</td>
<td>18%</td>
<td>4.7%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Pediatrics</td>
<td>4.7%</td>
<td>32%</td>
<td>36.7%</td>
<td>18%</td>
<td>8.7%</td>
</tr>
<tr>
<td>Neurology</td>
<td>55.3%</td>
<td>26.7%</td>
<td>4.7%</td>
<td>4.7%</td>
<td>8.7%</td>
</tr>
<tr>
<td>Cardiopulmonary</td>
<td>24%</td>
<td>24%</td>
<td>16%</td>
<td>24%</td>
<td>12%</td>
</tr>
<tr>
<td>Surgery</td>
<td>10%</td>
<td>36%</td>
<td>14%</td>
<td>14%</td>
<td>26%</td>
</tr>
<tr>
<td>Burns</td>
<td>20%</td>
<td>32%</td>
<td>32%</td>
<td>10%</td>
<td>14.7%</td>
</tr>
<tr>
<td>Internal medicine and Geriatric</td>
<td>26.7%</td>
<td>41.3%</td>
<td>13.3%</td>
<td>18.7%</td>
<td>0%</td>
</tr>
<tr>
<td>Obstetrics and Gynecology</td>
<td>4.7%</td>
<td>39.3%</td>
<td>46.7%</td>
<td>19.3%</td>
<td>0%</td>
</tr>
</tbody>
</table>

SR: Strongly related  R: Related  UC: Uncertain  U: Unrelated  SU: Strongly unrelated

### TABLE 3. PERCEPTION OF PHYSICAL THERAPY ROLE

<table>
<thead>
<tr>
<th>PT role</th>
<th>SR N (%)</th>
<th>R N (%)</th>
<th>UC N (%)</th>
<th>U N (%)</th>
<th>SU N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintain and improve physical function</td>
<td>77.3 %</td>
<td>18%</td>
<td>0%</td>
<td>4.7%</td>
<td>0%</td>
</tr>
<tr>
<td>Improve mobility</td>
<td>82%</td>
<td>13.3%</td>
<td>0%</td>
<td>4.7%</td>
<td>0%</td>
</tr>
<tr>
<td>Relief pain</td>
<td>40%</td>
<td>35.3%</td>
<td>10%</td>
<td>10%</td>
<td>4.7%</td>
</tr>
<tr>
<td>Improve balance</td>
<td>46%</td>
<td>40%</td>
<td>14%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Rehabilitation of postoperative patient</td>
<td>18%</td>
<td>14%</td>
<td>18%</td>
<td>27%</td>
<td>23%</td>
</tr>
<tr>
<td>Maintain and improve muscles strength</td>
<td>71%</td>
<td>10%</td>
<td>5%</td>
<td>4%</td>
<td>10%</td>
</tr>
<tr>
<td>Improve movement dysfunction</td>
<td>73.3%</td>
<td>22%</td>
<td>4.7%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Improve endurance</td>
<td>36.7%</td>
<td>36.7%</td>
<td>21.3%</td>
<td>5.3%</td>
<td>0%</td>
</tr>
</tbody>
</table>

**Fig 1. Perception of physical therapy modalities**

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Results of the forth question “What are your sources of information about PT profession?”

The results of this study represented that the most common source of information about PT profession was internet & researches with percentage of awareness 81.3% while conferences was considered as the lowest source with percentage of awareness 36.7%. The results also revealed that studying and work experiences represented high level of awareness with a percentage of 76.7% and 63.3% respectively. (Fig 2)

Results of the third question “which of the following do you think is one of PT role?”

Concerning of this question, most of the responses represented that the respondents had a good perception in relation to PT role. PT roles “maintain & improve function, improve mobility, and improve movement dysfunction” represented 95.3% for each of the total sample. The results also showed that the respondents had a lowest awareness by 68% for the PT role related to rehabilitation of postoperative patient. (Table 3)

Results of the fifth question: “To what extent you are convinced of the importance of physical therapy role as a member of medical team?”

Fig 3. Showed that 66 of the respondents (44%) were convinced of the importance of physical therapy role as a member of medical team by 60%-80%, while 48 of the total sample (32%) were convinced by 80%-100%.

DISCUSSION

This study was conducted to identify areas of deficits in physical therapy profession.
perception by physician and medical students in Sudan region, in addition to clarify the importance of physical therapy profession and highlight the role of physiotherapist as a member of medical team.

The results of this study indicated that there was a high awareness of PT subspecialty as orthopedic, neurology and internal medicine. This findings support other findings suggesting that physical therapists are best known for treatment of musculoskeletal conditions25,28. Additionally treatment of neurological conditions is more commonly recognized. Other subspecialty such as obstetrics and gynecology, burn and surgery lacked familiarity and this is similar to a previous study conducted by Sheppard23.

Regarding PT modality the results revealed that, there was a high awareness of exercises and also for manual therapy, electrotherapy and massage in contrast there was lack of awareness regarding traction and hydrotherapy. Parti and Liu29 concluded that traditional treatment such as physical exercise, massage, versus modern treatment, such as electrical stimulation and ultrasound are still widely associated with PT. The finding of our study related to exercise and massage is supported by public awareness14.

According to the results, the participant showed awareness regarding the physical therapy role related to improve mobility, improve function and relief pain which was supported by previous study14,27.

Regarding the subjects’ awareness related to sources of information about PT profession the study showed that internet, researches and conferences are the common sources respectively, in contrast studying and work experiences are less common. Sixty sex of the study sample represented that physiotherapist is considered as an important member of the medical team by a percentage of 60%-80%.

**CONCLUSION AND RECOMMENDATION**

From the previous, the study concluded that there is deficits in the perception of PT in different areas. This lack of awareness must be overcome. As a high standard of patient care is the main goal of medical team so effective communication between physician and physical therapist is necessary to ensure this level of care. As well as physical therapists should center efforts on marketing to physicians and medical students28. Continuing education programs is suggested to increase PT profession awareness. Additionally it is recommended that mass media should be improved in its accuracy about PT29.

Further studies should be conducted on Saudi physician only. As well as perception of PT should be evaluated in relation to patients.

**AKNOWLEDGEMENT**

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**REFERENCES**

12. Wikipedia. Health care provider: Wikimedia


