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REVIEW

Muscle Atrophy in Intensive Care Unit Patients

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ABSTRACT

Introduction: The muscle atrophy is one of the most important and frequent problems observed in patients in Intensive Care Units. The term describes the disorder in the structure and in the function of the muscle while incidence rates range from 25-90 % in patients with prolonged hospitalization. **Purpose:** This is a review containing all data related to the issue of muscle atrophy and is especially referred to its causes and risk factors. The importance of early diagnosis and early mobilization are also highlighted in the study. **Material and methods:** a literature review was performed on valid databases such as Scopus, PubMed, Cinhal for the period 2000-2013 in English language. The following keywords were used: loss of muscle mass, ICU patients, immobilization, bed rest. **Results:** From the review is concluded that bed rest and immobilization in order to reduce total energy costs, are the main causes for the appearance of the problem. The results of the reduction of the muscle mass mainly affect the musculoskeletal, cardiovascular and respiratory system. The administration of the cortisone, the immobility, the sepsis and hyperglycemia are included in the risk factors. The prevention is the primary therapeutic agent and this is achieved due to the early mobilization of the patients, the use of neuromuscular electrical stimulation and the avoidance of exposure to risk factors. **Conclusions:** The prevention of muscle atrophy is a primary goal of treatment for the patients in the ICU, because it reduces the incidence of the disease, reduces the time spent in ICU and finally improves the quality of patients' life.

Key words : ICU patients, loss of muscle mass, immobilization, bed rest

1. INTRODUCTION

The developments in the therapeutic techniques and in the care of the critically ill patients have contributed to an increased survival of these patients. At the same time, it has led to the finding that the consequences of the patients hospitalization in the Intensive Care Unit (ICU) due to an acute illness affect these patients not only after the end of the acute phase of the illness, but also after their leaving from the hospital. One of these consequences is the appearance of muscle atrophy or muscle weakness of ICU (ICU-acquired weakness: ICU-AW) as it is reported, which is a frequent clinical problem in the ICU.

The muscle weakness of the critically ill patient is one of the most common problems seen in the patients hospitalized in the intensive care unit (1) and it is characterized by bilateral, symmetrical muscle weakness which is not associated with a preexisting neuromuscular problem (2). This weakness may be due to axonal polyneuropathy (critical illness polyneuropathy), may be due to myopathy (critical illness myopathy) or due to a combination of the two previously mentioned situations (critical illness polyneuromyopathy)(3).

Bed rest deemed to be necessary for all the diseases and for all the patients of ICU and the effects of the prolonged stay in the ICU contribute significantly in reducing the mobility of these patients. Long-term treatment of the critically ill patient in ICU causes a decrease in hydrostatic pressure within the cardiovascular system, an unloading of the forces of the skeletal muscles and a decrease of the total energy expenditure when the corresponding production of power is minimized. The results could adversely affect most of the systems including the musculoskeletal, the cardiovascular and finally

the circulatory, systems which present the most pronounced weakening (4).

The term "loss of muscle mass in ICU" describes the disturbances in the structure and in function of the muscles (5). The clinical picture of the muscular atrophy is characterized by a generalized muscle weakness, which in severe cases can lead to tetraplegia, by a reduction or abolition of the tendon reflexes, and a difficulty in weaning from the ventilator(6). The main factors that cause loss of muscle mass are microcirculatory disturbances which affect the peripheral nerves and the skeletal muscles, the presence of systemic inflammatory response (systemic inflammatory syndrome SIRS), the sepsis, and the use of drugs with inhibitory activity on the muscular system as well as on the nervous system—neuromuscular junction (corticoids, neuromuscular blockers)(1,7).

Prolonged bed rest, the sedation and the unavoidable immobilization also contribute to the appearance of this problem. The immobilization therefore is a factor that helps the development of muscular atrophy (8). In a recent studies was found that the electrical stimulation of the muscles, the early mobilization of the patients and the use of the neuromuscular electrical stimulation can substantially mitigate the muscular atrophy(1,9).

2. EPIDEMIOLOGICAL EVIDENCE

Reported incidence of the disease varies significantly based on diagnostic methods (physical examination, electromyography, biopsy) and timing of neurologic examination(1,2). The percentage of critically ill patients in ICU with multi-organ failure who develop muscle mass loss reaches 100 %. Muscle atrophy develops in 80 % of patients receiving more

than seven days of mechanical ventilation. In patients undergoing mechanical ventilation for four days the incidence rate of muscle loss is reduced to 50 % and finally to those receiving of mechanical ventilation for three days, the incidence rate is reduced to 33 %(10).

One of the most important factors regarding the muscle atrophy is the diagnosis which can be either clinically or through electromyographic findings. The effect of muscle mass loss ranges from about 25% when the diagnosis is by clinical criteria to 90% when EMG criteria are solely used(1,7). Another factor affecting a lot the incidence of muscular atrophy is the timing of the clinical examination. In studies using purely clinical criteria the diagnosis was after the awakening of the patient(1,7). The clinical diagnosis requires the cooperation of the patient so it is not possible to assess the presence of muscle atrophy in critically ill patients if they don't have a satisfactory level of consciousness.

One more factor affecting the incidence of muscle mass loss is the study population. There are several differences in the studies as it concerns the inclusion criteria (mechanical ventilation and ICU stay of more than 7 days) and the exclusion criteria (coexisting illnesses) (11,12). Most of the studies also use a small sample of patients with muscular atrophy. This fact complicates the assessment of the actual impact of the muscle mass loss on ICU patients.

3. ETIOLOGY

The ICU-acquired weakness is multifactorial. It can be apparent both directly due to the toxic action of drugs and due to the disruption of the microcirculation and also indirectly due to muscle atrophy from prolonged immobilization.

More specifically, during sepsis, the microcirculation is disturbed and as a result decreased irrigation and organ dysfunction is caused. Endothelial cells are protected via the self regulation mechanism and automatically nitric oxides are released and vasodilation is caused. The vessels of the peripheral nerves do not have self-regulation mechanism, and this fact makes the peripheral nerves vulnerable to hypoxia due to mitochondrial damage (13). Additionally, the cytokines released during sepsis increase the permeability of the microcirculation. The pathogenetic role of cytokines has been demonstrated, but the exact mechanisms remain unclear. The current view today is that cytokines and free radicals which are associated with SIRS adversely affect the microcirculation and muscles, causing neuronal hypoxia, axonal degeneration and muscular damage (14). It should not be forgettable that the catabolic processes contribute to the reduction of muscle mass, mainly through the catabolism of myosin. A typical example is that of calpain, which is an important proteolytic enzyme of the skeletal muscles. The production and maintenance of muscle mass depends on the balance between anabolism and catabolism of the protein. The catabolism is increased in many pathological conditions, such as cachexia and sepsis. The bed rest and the toxic drugs have also effect on the muscle. The calpain regulates the production cycle of muscular proteins and there is evidence of increased activity of calpain in skeletal muscles of patients with ICU-AW (15).

The prolonged bed rest, even in healthy people leads to a significant loss of muscle mass and muscle strength due to a reduction in anabolic processes and at the same time an in-

crease in catabolic processes of the muscle proteins. Studies in healthy population have shown that the loss rate is between 4-5% every week of immobilization (16). The interaction of immobilization in conjunction with sepsis or systemic inflammatory response syndrome enhances the loss of muscular proteins, which can reach 2/3 for the first 5 days (17).

4. RISK FACTORS-TREATMENT

A standard treatment for the ICU-AW has not been found. However, the effort to prevent the syndrome focuses on the control of those factors (pharmaceutical and non-pharmaceutical) which have been implicated in its appearance, such as the following:

Corticosteroids: The role of corticosteroids in the loss of muscular mass of critically ill patients, has been examined in detail due to their catabolic action. The findings, however, of these studies are contradictory. It is supported in the literature that the animals who receive corticosteroids develop muscle atrophy (18). Studies in rodents reveal that there is an increase in the number of glucocorticoid receptors, indicating that these muscles are hypersensitive to steroids (5).The harmful effect of corticosteroids on muscle mass in humans and particularly in ICU patients has been also observed in several studies (7). The researchers suggest that patients who are not hospitalized in the ICU but they receive corticosteroids are also prone to develop myopathy as well as muscle atrophy. However, in many studies the sample size is small (2-27 patients) and there are unreliable criteria regarding the dose and the duration of corticosteroid administration. It is also important the activity or the physical condition of the patient before the onset of serious illness to be taken into account (5).

Neuromuscular blockers: The neuromuscular blocking agents have been associated directly with the loss of muscle mass in ICU patients (1). A pathogenetic mechanism is probably responsible for the functional denervation of the skeletal muscle which results in the acceleration of its degradation. However, in another study the loss of muscle mass is not related to the use of neuromuscular blockers (19). Nonetheless, the harmful effect of neuromuscular blockers in the body during their continuous intravenous infusion cannot be safely excluded, as there is a lack of studies regarding this issue.

Aminoglycosides: Aminoglycosides are used heavily in the ICU for severe infections. It was found, however, that their use is a major risk factor for the occurrence of muscular atrophy in ICU patients (1). According to the previous mentioned study, the toxic effect of aminoglycosides on both vestibular and cochlear nerve is apparent, and it also contributes to the development of loss of muscle mass. The above findings have been confirmed but the potential neurotoxic effects have not been evaluated by electrophysiologic monitoring. On the other hand, in other studies the use of aminoglycoside was not associated with loss of muscle mass (20). This may be due to lack of independent clinical results or due to insufficient sample size.

Colistin: It is an antibiotic from the polymyxin family, the use of which has become known in recent years due to the presence of resistant bacteria susceptible to colistin. The use of colistin is connected to toxicity, mainly to nephrotoxicity and neurotoxicity, which are mild in nature and they disappear after the early discontinuation of the antibiotics(21).

Direct toxic effects of drugs and toxins: According to the literature, it is likely that certain endotoxins have direct toxic effects on the muscles and nerves (1,7). The action of these toxins is worsened due to endothelial dysfunction and then due to increased vascular permeability, which disrupts the vascular barrier and allows the entry of toxins in the interstitium. More specifically, medicines such as inotropes, the vasoconstrictors and the catecholamines have been identified as risk factors for muscle loss in critically ill patients in ICU (1).

Malnutrition: A major factor of muscle mass loss is the malnutrition of protein energy which is experienced by critically ill patients in ICU. The hospitalized patients usually receive less than 60% of total calories required for their needs. This fact affects the ICU patients, who are particularly sensitive and they demonstrate an unjustified malnutrition. The protein malnutrition in conjunction with the pressures of increased metabolism leads to a substantial loss of proteins via amino acids that are mainly derived from the muscles (22,23).

Multi-organ failure: A high correlation between the prolonged hospitalization and the simultaneous failure of two or more organ systems is documented in the literature (7). The connection between the muscle atrophy and the multi-organ failure raises questions as to whether the loss of muscle mass is part of a critical illness or represents another problem in a syndrome of multi-organ failure (5).

Parenteral Nutrition: Some case reports link the ICU-AW with the administration of parenteral nutrition. The hypothesis in these cases is that the use of intravenous lipids with high levels of polyunsaturated fatty acids causes harmful effects on peripheral nerves (24). However in other cases it is hypothesized that the parenteral nutrition is associated with various metabolic disorders such as hyperglycemia, hyperosmolarity and hypernatremia, which may worsen the disorders of the microcirculation in patients with SIRS and sepsis (25).

Sepsis: There is a high correlation between sepsis and appearance of muscle loss in patients hospitalized in the ICU (1,7). The electromyographic disorders are found in all the patients with septic shock during the first week of ICU stay (26). However, the pathophysiological link between sepsis and loss of muscle mass is unclear. The neuromuscular dysfunction appears of high correlation with sepsis and additionally it seems to be associated with hypotension and reduction of blood flow resulting in a change of the energy supply of the muscles, particularly in the region where there is a decreased irrigation (27). Although there is a strong correlation between sepsis and loss of muscle mass, sepsis is not a prerequisite for the development of muscle mass. Patients who are not septic may also develop muscular atrophy (5).

Immobilization: The harmful effects of immobility in skeletal muscle of ICU patients have been well documented as a factor that increases morbidity and contributes to the appearance of muscular atrophy in critically ill patients (28). The muscular tissue is a highly supple organ, the deconstruction and the reconstruction of which is in dynamic equilibrium with the mechanical effects and the needs of the body. Immobilization is a medical condition for the muscle that activates the catabolic processes of the muscles (29). The prolonged bed rest leads to a decreased synthesis of muscle protein, increased urinary nitrogen (indicating the muscle catabolism) and reduced muscle mass, especially in the lower extremities (30).

5. EARLY DIAGNOSIS

The ICU-AW can occur early during hospitalization in the ICU and as such it is important that the doctors are able to determine which patients are at risk. Additionally, frequent and regular neuromuscular exams help in the early diagnosis of ICU-AW. These exams include an assessment of the tendon reflexes and the movement, the tone and the muscle strength. As the reliable assessment of the muscular strength requires the patient's cooperation, the muscle weakness can only be assessed after the waking of the patient and after the regaining of full communication. Based on the above, it is crucial to apply a protocol of periodic interruption of the sedation and assessment of the patient. The clinical diagnosis is performed using the scale of the MRC (Medical Research Council) for the muscular force, which is a convenient and reliable tool (11, 12, 31). With the MRC scale, the muscle strength is assessed in 12 muscle groups (6 in each half of the body, three in the upper extremities and three in the lower extremities). The maximum sum that can be achieved in this way is 60 and the minimum zero. The patient is considered to have ICU-AW if the value of MRC is less than 48 (31, 32).

6. EARLY MOBILIZATION

Physical activity and exercise in general is one of the main indicators for the protection and promotion of health. In ancient Greece the exercise had an important role in people's lives and it was part of the whole education (33). The words of the ancient Greeks' "healthy mind in a healthy body" were used in antiquity and it means that ideal citizen was the one who was well exercised and accomplished in mind and in soul (34, 35). Today is scientifically documented that the beneficial effects of exercise include all the patients, such as the chronically ill patients or those who are hospitalized in Intensive Care Units (ICU), contributing effectively to restore their health and to prevent complications from the prolonged bed rest (23).

It is important an 'individual mobilization program for each patient' to be designed after his/her admission to the ICU (23,36). The mobilization techniques should be proportionate with the capabilities of the patient, but also with his/her level of cooperation. The appropriate choice of technique requires a thorough physiotherapy assessment, which includes the study of the patient's medical history and an evaluation of the cardiac and respiratory reserve as well as of other factors relating to the overall clinical picture of the patient. There are many techniques that can be used, such as the positioning the patient on the bed, the sitting on the edge of the bed, the transfer to the chair, the orthostatic, the walking technique, the balance retraining, and the implementation of passive, active, assisted exercises or exercises with resistance, as well as the use of the ergometer bicycle on the bed.

As the recent studies demonstrate that the mobilization is safe and feasible, the interest of the researchers focuses on the design of an mobilization algorithm, facilitating the rapid start of mobilization of the patient (37, 38, 39). The mobilization contributes to the awakening of the patient and to the prevention of thrombophlebitis, muscle atrophy and weakness of the respective muscle groups. It also contributes to the treatment of pressure ulcers, the facilitation of vascular circulation, the treatment of systemic inflammation and at the

end it seems to accelerate the weaning the patient from the ventilator (40).

7. NEUROMUSCULAR ELECTROSTIMULATION (NMES)

The neuromuscular electrical stimulation is an alternative way of exercise, which has been used in both healthy and patients. The aim is the activation of the skeletal muscles through the application of electricity and the muscle contraction. Thus, the muscle exercise is implemented without the presence of voluntary movement of the body parts (41). It has been used in particular to patients with severe Chronic Obstructive Pulmonary Disease (COPD) and Chronic Heart Failure (CHF). These patients are not capable to participate in a more active exercise program (42, 43). This intervention has been shown to be effective, helping in maintaining the muscle mass and strength (44), the faster weaning from the ventilator and the prevention of ICU-AW (45, 46). Daily sessions of electrical neuromuscular stimulation to the two legs resulted in significantly lower rates of muscle weakness.

8. CONCLUSIONS

The loss of muscle mass is one of the most important and frequent problems observed in patients hospitalized in the ICU, affecting the cardiovascular, the respiratory and the circulatory system. It is mainly caused by the prolonged bed rest, the sedation and the immobilization. The mitochondrial dysfunction, the changes in the microcirculation, the release of pre-inflammatory cytokines, the inactivation of sodium channels of skeletal muscles, and finally the increase in the calpain expression are the mechanisms associated with the pathophysiology of muscular atrophy. The causes of muscle mass loss are both pharmaceutical and non-pharmaceutical.

The prevention of muscle atrophy depends on the immediate mobilization of patients, the use of the neuromuscular electrical stimulation and the avoidance of the risk factors.

CONFLICT OF INTEREST: NONE DECLARED.

REFERENCES

- Nanas S, Kritikos K, Angelopoulos E, Siafaka A, Tsirikiki S, Porriazi M, et al. Predisposing factors for critical illness polyneuropathy in a multidisciplinary intensive care unit. *Acta Neurol Scand.* 2008; 118(3):175-81
- De Jonghe B, Bastuji-Garin S, Durand MC, Malissin I, Rodrigues P, Cerf C, et al. Respiratory weakness is associated with limb weakness and delayed weaning in critical illness. *Crit care med.* 2007; 35(9):2007-2015.
- De Jonghe B, Sharshar T, Hopkinson N, Outin H. Paresis following mechanical ventilation. *Curr Opin Crit Care.* 2004; 10(1):47-52.
- Stuempfle KJ, Drury DI G. The physiological consequences of bed rest. *Journal of exercise physiology.* 2007; 10(3):32-41.
- Johnson KL. Neuromuscular complications in the intensive care unit. *Critical illness polyneuropathy.* 2007; 18(2): 167-180.
- Bolton CF. Neuromuscular manifestations of critical illness. *Muscle Nerve.* 2005; 32(2):140-163.
- De Jonghe B, Lacherade JC, Sharshar T, Outin H. Intensive care unit – acquired weakness: Risk factors and prevention. *Critical Care Med.* 2009; 37(10suppl): 309-315.
- Truong AD, Fan E, Brower RG, Needham DM. Bench -to-bedside review: Mobilizing patients in the intensive care unit—from pathophysiology to clinical trials. *Critical Care.* 2009; 13(4): 216.
- Gerovasili V, Tripodaki E, Karatzanos E, Pitsolis T, Markaki V, Zervakis D, et al. Short-term systematic effect of electrical muscle stimulation in critically ill patients. *Chest.* 2009; 136(5):1249-56
- Van Mook WN, Hulsewe-Evers R. Critical illness polyneuropathy. *Current Opinion in Critical Care.* 2002; 8(4):302-310.
- Hermans G, Clerckx B, Vanhullebusch T, Segers J, Vanpee G, Robbeets C, et al. Intraobserver agreement of medical search council sum score and hand-grip strength in the intensive care unit. *Muscle & Nerve.* 2012; 45(1):18-25.
- Hough CL, Lieu BK, Caldwell ES. Manual muscle strength testing of critically ill patients: feasibility and intraobserver agreement. *Critical Care.* 2011; 15:R43.
- De Sèze M, Petit H, Wiart L, Cardinaud JP, Gaujard E, Joseph PA, Mazaux JM, Barat M. Critical illness polyneuropathy: a 2-year follow-up in 19 severe cases. *Eur Neurol.* 2000; 43(2):61-69.
- De Letter MA, Schmitz PI, Visser LH, Verheul FA, Schellens RL, Op de Coul DA, van der Meché FG. Risk factors for the development of polyneuropathy and myopathy in critically ill patients. *Crit Care Med.* 2001; 29(12):2281-2286.
- Di Giovanni S, Mirabella M, D'Amico A, Tonali P, Servidei S. Apoptotic features accompany acute quadriplegic myopathy. *Neurology.* 2000; 55(6):854-858.
- Stein TP, Wade CE. Metabolic consequences of muscle disuse atrophy. *J Nutr.* 2005; 135(7):1824-1828.
- Herridge MS, Cheung AM, Tabsey CM, Matte-Martyn A, Diaz-Granados N, Al-Saidi F et al. One year outcomes in survivors of the acute respiratory distress syndrome. *N Engl J Med.* 2003; 348 (8): 683-693.
- Rich MM, Pinter MG. Crucial role of sodium channel fast inactivation in muscle fiber inexcitability in a rat model of critical illness myopathy. *Journal of Physiology.* 2003; 547(2):555-566.
- Papazian L, Forel JM, Gacouin A, Penot-Ragon C, Perrin G, Loundou A, et al. Neuromuscular blockers in early acute respiratory distress syndrome. *The new England Journal of medicine.* 2010; 363(12):1107-1116.
- Heier CR, Didonato CJ. Translational readthrough by the aminoglycoside geneticin (G418) modulates SMN stability in vitro and improves motor function in SMA mice in vivo. *Human Molecular Genetics.* 2009; 18(7):1310-1322.
- Falagas ME, Kasiakou SK. Toxicity of polymyxins: a systematic review of the evidence from old and recent studies. *Critical Care.* 2006; 10(1):R 27.
- Hise ME, Halterman K, Gajewski BJ, Parkhurst M, Moncure M, Brown JC. Feeding practices of severely ill intensive care unit patients: an evaluation of energy sources and clinical outcomes. *Journal of Am Diet Association.* 2007; 107(3):458-465.
- Needham DM. Mobilizing patients in the intensive care unit: improving neuromuscular weakness and physical function. *JAMA.* 2008; 300(14):1685-90.
- Marino PL, Millili JJ. Possible role of dietary lipids in critical illness polyneuropathy. *Intensive Care Med.* 1998; 24(1):87.
- Garnacho-Montero J, Madrazo-Osuna J, García-Garmendia JL, Ortiz-Leyba C, Jiménez-Jiménez FJ, Barrero-Almodóvar

- A, et al. Critical illness polyneuropathy: risk factors and clinical consequences. A cohort study in septic patients. *Intensive Care Med.* 2001 ; 27(8) :1288–1296.
26. Dhand UK. Clinical approach to the weak patient in the Intensive Care Unit . *Respiratory Care.* 2006 ; 51(9):1024-1041.
 27. Lanone S, Taille C, Boczkowski J, Aubier M. Diaphragmatic fatigue during sepsis and septic shock. *Intensive Care Med.* 2005 ; 31(12):1611-1617.
 28. Schmutzhard E, Pfausler B. It's not only biochemistry: a possible pathogenetic role of immobilization/immobility in critical illness polyneuromyopathy. *Critical Care Med.* 2008 ; 36(3):1021-1022.
 29. Strasser EM , Wessner B, Roth E. Cellular regulation of anabolism and catabolism in skeletal muscle during immobilization, aging and critical illness. *Wiener Klinische Wochenschrift .* 2007 ; 119(11-12): 337-348.
 30. Kortebein B, Ferrando A, Lombeida J, Wolfe R, Evans WJ. Effect of 10 days of bed rest on skeletal muscle in healthy older adults . *JAMA.* 2007 ; 297(16):1772-1774.
 31. Ali NA, O'Brien JM Jr, Hoffmann SP, Phillips G, Garland A, Finley JCW et al. Acquired weakness, handgrip strength and mortality in critically ill patients. *Am j Respir Care Med.* 2008 ; 178(3):261-268.
 32. Stevens RD, Marshall SA, Cornblath DR, Hoke A, Needham DM, De Jonghe B, et al. A framework for diagnosing and classifying intensive care unit- acquired weakness. *Crit Care Med.* 2009 ; 37(10): 299-308.
 33. Kourkouta L., Plati, P., Prokopiou E. A healthy mind in a healthy body. 39th National Nursing Conference. Volos, 15-18 May 2012.
 34. Papathanassiou I, Sklavou M, Kourkouta L. Holistic nursing care: theories and perspectives. *American Journal of Nursing Science.* 2013 ; 2(1) : 1-5.
 35. Kourkouta L., lafri M., Tsiotsiou B., Stroggilou B. Exercise and Mental Health in Ancient Greece. 40th Psychiatric Conference on Primary Health Care. Kylini Ilia, 1–4/6/2012.
 36. Morris PE, Griffin L, Berry M, Thomson C, Duncan RH, Winkelmann C, Hopkins R, et al. Receiving early mobility during an intensive care unit admission is a predictor of improved outcomes in acute respiratory failure. *Am J Med Sci.* 2011 ; 341(5): 373-377.
 37. Bailey P, Thomsen E G, Spuhler J V, Blair R, Jewkes J, Rodriguez L, Hopkins OR. Early activity is feasible and safe in respiratory failure patients *Crit Care Med.* 2007 ; 35 (1): 139-145.
 38. Perme C, Chandrashekar R. Early mobility and walking program for patients in intensive care units: creating a standard of care. *Am J Crit Care.* 2009 ; 18(3):212-221.
 39. Hanekom S, Gosselink R, Dean E, Van Aswegen H, Roos R, Ambrosimo N, Louw Q. The development of a clinical management algorithm for early physical activity and mobilization of critically ill patients: synthesis of evidence and expert opinion and its translation into practice. *Clin Rehabil.* 2011 ; 25 (9):771-787.
 40. Gosselink R, Bott J, Johnson M, Dean E, Nava S, Norrenberg M, et al . Physiotherapy for adult patients with critical illness recommendations of the European Respiratory Society and European Society of Intensive for critically ill patients Task Force on physiotherapy Care Medicine . *Int Care Med.* 2008 ; 34(7):1188-1199.
 41. Bouchla A, Karatzanos E, Dimopoulos S, Tasoulis A, Agapitou V, Diakos N, et al. The addition of strength training to aerobic interval training : effects on muscle strength and body composition in CHF patients. *J of Cardiopulmonary rehab & prevention.* 2011 ; 31(1): 47-51.
 42. Vivodtzev I, Pepin JL, Vottero G, Mayer V, Porsin B, Levy P, et al. Improvement in quadriceps strength and dyspnea in daily tasks after 1 month of electrical stimulation in severely deconditioned and malnourished COPD. *Chest.* 2006 ; 129(6):1540-48.
 43. Harris S, Le Maitre J, Mackenzie G, Fox KA, Denvir MA. A randomized study of home-based electrical stimulation of the legs and conventional bicycle exercise training for patients with chronic heart failure. *Eur Heart J.* 2003 ; 24(9): 871-878.
 44. Meesen RL, Dendale P, Cuyppers K, Berger J, Hermans A, Thijs H, et al. Neuromuscular Electrical Stimulation as a possible means to prevent muscle tissue wasting in artificially ventilated and sedated patients in the intensive care unit: a pilot study. *Neuromodulation.* 2010 ; 13(4):315-21.
 45. Gerovasili V, Stefanidis K, Vitzilaios K, Karatzanos E, Politis P, Koronaios A, et al . Electrical muscle stimulation preserves the muscle mass of critically ill patients: a randomized study. *Crit Care.* 2009 ; 13(5): R161.
 46. Routsis C, Gerovasili V, Vasileiadis I, Karatzanos E, Pitsolis T, Tripodaki E, et al. Electrical muscle stimulation prevents critical illness polyneuropathy: a randomized parallel intervention trial. *Crit Care.* 2010 ; 14(2):R74.