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EXERCISE-INDUCED PHYSIOLOGICAL LUBRICATION MECHANISMS DISSIPATING ARTHRITIC JOINT PAIN

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ABSTRACT

Arthritis is a painful inflammatory joint disease that limits the affected joint's range of motion (ROM), muscle strength and endurance. As a result, cardiorespiratory capacity, physical functioning and quality of life of an individual are negatively affected. Certain physiological interventions do help alleviate joint pain and stiffness. This paper discusses the exercise-induced physiological lubrication mechanisms that dissipate arthritic joint pain. Aquatic- and land-based exercise and therapeutic interventions are also presented.

Keywords: Arthritis; Exercise; Lubrication mechanisms.

INTRODUCTION

The term arthritis covers a number of joint inflammatory conditions. The most common types of arthritis are rheumatoid arthritis (RA) and osteoarthritis (OA) (Durstine & Moore, 2011). RA is a chronic, systemic, autoimmune and inflammatory disorder that affects joints, tendons, tendon sheaths, and bursae (Cooney *et al*., 2011). The main symptoms of RA are muscle and joint stiffness, pain, swelling, muscle wasting and reduced muscle strength (Cooney *et al*., 2011). Methotrexate is a common medicinal treatment for RA to reduce further joint damage (Cooney *et al*., 2011). Chronic use of Methotrexate in dosage larger that 25mg per week may lead to liver and kidney dysfunction, mouth sores, diarrhoea, anaemia and temporary hair loss (Muller *et al.* 2015).

Osteoarthritis, however, is the structural and functional failure of the synovial joint leading to subchondral bone alteration, meniscal degeneration, a synovial inflammatory response, and osteophyte formation (Hunter & Eckstein, 2009). A prominent feature of OA is articular cartilage loss (Chen *et al.,* 2016). Predisposing factors of OA are trauma, incorrect loading of joints and diseases (Richmond *et al*., 2013). Ibuprofen is a non-steroidal anti-inflammatory drug often prescribed to osteoarthritic patients. Chronic use of ibuprofen (Advil, Midol and Nuprin) is associated with stomach bleeding, cancer development and cardiac arrests (Aarts *et al.,* 2015; Matos & Jordan, 2015). Glucosamine chondroitin (GC) is another popular pharmacological option to relieve arthritic symptoms (Hart, 2006). Once the OA becomes chronic, GC loses its potency and patients often seek stronger medication and alternate therapies (Durstine & Moore, 2011). Often students and patients are informed that structured rehabilitative exercises reduce arthritic joint pain and improve ROM, but the exercise-induced physiological lubrication mechanisms are rarely discussed (Kim *et al.,* 2012; Davies & Nelson, 2015). The distinctiveness of this paper lies in the discussion of the exercise-induced physiological lubrication mechanisms that dissipates arthritic joint pain. Further, the benefits of aquatic- and land-based exercises are presented.

EXERCISE AS A FUNDAMENTAL TOOL IN MANAGEMENT OF ARTHRITIS

Many medical professionals often refer arthritic patients to physiotherapists and biokineticists for exercise-induced symptom relief (Hart, 2006). Arthritis affects arthrokinematics, which describes the motion occurring between articular joint surfaces (Mansfield & Neumann, 2009). Intrinsic risk factors affecting the arthrokinematics include muscle contractures, muscle weakness, abnormal force-couple relationships between agonist and antagonist muscles, abnormally shortened peri-articular connective tissue and osteophyte development (Durstine & Moore, 2011). Roubenoff (2003) has claimed that regular strengthening exercise improves the strength of inflamed muscles and thereby arthritic joint function.

EFFECT OF INACTIVITY ON ARTHRITIC JOINT FUNCTION

The appreciation of exercise-induced arthritic relief becomes apparent when the adverse effects of inactivity are highlighted. The effect of joint inactivity should be viewed by looking at the changes in the muscle, articular cartilage and peri-articular connective tissue of joints. The morphological changes that these structures undergo due to inactivity increases the vicious cycle of pain, weakness, muscle wasting and poor quality of life experienced by arthritic patients.

Effects of joint inactivity on voluntary muscles

Changes to muscle morphology following inactivity include; atrophy, reduction in myofibrils number and diminished oxidative capacity. The dwindling number of myofibrils is replaced with fatty tissue, which affects muscle’s strength and endurance. Arthritic patients are 30% weaker than their aged-matched counterparts (Cooney *et al.,* 2011). Muscle wasting is the primary contributor of this loss of muscle strength. Progressive resistance training has proven to be successful in increasing the muscle strength and mass in arthritic joints (Flint-Wagner *et al.,* 2009). A sedentary lifestyle causes the following histological changes that adversely affect a muscle’s oxidative capacity: decreased adenosine triphosphate, adenosine diphosphate, creatine phosphate, creatine, glycogen and mitochondria number and size (Cooney *et al.,* 2011; Pinto *et al.,* 2016). Arthritic patients are often less physically active and as a result they have poor aerobic capacities that are 20-30% lower than age-matched healthy controls (Cooney *et al.,* 2011). This reduced aerobic capacity has been associated with Chronic Heart Diseases (CHD) and as a result reduced longevity in these inactive individuals (Law *et al.,* 2010; Metsios *et al.,* 2010).

Effect of joint inactivity on articular cartilage

The severity of inactivity on the articular cartilage depends on the joint position, duration of inactivity and weight bearing (Hunter & Eckstein, 2009; Cooney *et al.,* 2011). The articular cartilage of inactive joints becomes thinner because the proteoglycan concentration decreases and the extracellular matrix organisation declines. During joint immobility there is constant intra-joint pressure, which precipitates necrosis of articular cartilage. Exercise causes fluctuations in intra-joint pressure, increases proteoglycan concentration, extracellular matrix organisation and thickness of the articular cartilage (Hunter & Eckstein, 2009; Cooney *et al.*, 2011).

Effects of joint inactivity on peri-articular connective tissue

Peri-articular connective tissue includes the ligaments, tendons, fascia and synovial membranes that occur in joints. Joint inactivity facilitates a reduction of glycosaminoglycan (GAG) and water content in the ground substance, causing reduction of extracellular matrix. The decrease in the property of the ground substance allows more cross-link formation to occur within the peri-articular tissue that precipitates contractures. Regular joint mobilisation through exercise prevents cross-link formation and joint stiffness (Hunter & Eckstein, 2009).

PHYSIOLOGICAL LUBRICATION MECHANISMS OF EXERCISE

Pain reduces the joint mobility of arthritic patients, which in turn leads to muscle atrophy and weakening (Hunter & Eckstein, 2009). Despite synovial joints being subjected to diverse weight-bearing loads, the articular surfaces in the joints are designed to experience minimal wearing out (Marieb, 2004; Ellapen & Paul, 2015). These mechanisms include the boundary lubrication mechanism (BLM), the fluid-film lubrication mechanism (FFLM) and the weeping willow mechanism (Yousif, 2008). The different mechanisms complement each other during joint movement (Yousif, 2008). The physiological mechanisms of how exercise can improve joint arthrokinematics are presented here by discussing the various lubrication mechanisms.

Boundary lubrication mechanism (BLM)

Boundary lubrication occurs while a film of synovial fluid is present when articulating surfaces move against each other, preventing direct contact between them. The synovial fluid is a lubricating film that adheres to the articulating joint surfaces and decreases intra-joint friction. BLM is extremely effective during open kinetic chain exercises, but loses its potency during weight-bearing activities or closed kinetic chains exercises (Yousif, 2008).

Fluid-film lubrication mechanism (FFLM)

Fluid-film lubrication is a thick synovial fluid-film, which smoothens the irregularities of articulating joint surfaces. This thick fluid-film increases the cushioning between the articulating surfaces by keeping them further apart, regardless of the weight-bearing load. FFLM is effective during closed kinetic chain exercises (Yousif, 2008).

Weeping willow mechanism

The weeping willow mechanism is the process that dispels a continuous film of synovial fluid into the joint to facilitate either the BLM and/or the FFLM. Yousif (2008) has described the weeping willow mechanism as a special type of self-acting hydrostatic-bearing mechanism that is activated when articular cartilage from opposing surfaces press against each other, wringing out synovial fluid from the synovial bursae within the joint. The weeping willow mechanism is only activated during joint motion and is optimal during regular movement patterns (Marieb, 2004; Ellapen & Paul, 2015). Therefore, it is imperative that arthritic patients perform controlled supervised exercises and do not adopt a sedentary lifestyle.

TYPES OF EXERCISES TO BENEFIT ARTHRITIC PATIENTS

Most arthritic patients lead sedentary lifestyles that may precipitate the following comorbidities: obesity, hypertension, osteoporosis, diabetes mellitus and CHD (Ernest *et al.*, 2015; Hoes *et al.*, 2015; Kiani *et al.*, 2015). Durstine and Moore (2011) recommend that arthritic patients initially seek consent from their medical practitioner to perform exercises in an attempt to reduce arthritis symptoms. Furthermore, arthritic patients should consult a physiotherapist or biokineticist to prescribe safe and effective rehabilitative exercises.

The exercise goals of arthritic patients are to keep the joints mobile, prevent obesity, reduce the risk of osteoporosis and diabetes mellitus and CHD, as well as increase aerobic capacity (VO_{2max}), muscle strength and endurance (Roubenoff, 2003). Bjersing *et al.* (2012) and French *et al.* (2013) reported that controlled regular exercises, such as range of motion (ROM), aerobic and strengthening reduces arthritic symptoms, thereby improving quality of life.

Range of motion exercises may be either passive, active or active-assistive. Passive ROM exercises should be executed during acute joint inflammation or when the patient is unable to move the joint due to spasm and/or pain (Nolte & Janse Van Rensburg, 2013). Active ROM exercises are most preferred. It is recommended that active ROM exercises be performed 2-3 times daily with 5-6 repetitions. Passive ROM exercises should be completed at least twice in a rehabilitative session (Nieman, 2000). Many arthritic patients have a reduced aerobic capacity due to their sedentary lifestyle. Nolte and Janse Van Rensburg (2013) recommend aerobic exercises 3-5 days per week and performed at a moderate intensity, to ensure these patients are capable of performing daily living activities comfortably. Aerobic exercise includes walking, swimming or cycling. Nolte and Janse Van Rensburg (2013) reported that adequate strength training protects and preserves the health of arthritic joints during weight-bearing activity. Strengthening exercises may utilise an isometric, isotonic or isokinetic contraction to bring about muscle strength and endurance.

Hydrotherapy is a popular and successful therapeutic exercise intervention adopted to rehabilitate arthritic patients (Zamuner *et al.*, 2015; Lyp *et al.*, 2016). The benefits of hydrotherapy for arthritic patients include: off-loading of painful arthritic joints due to the water's buoyancy, thereby relieving stress and pain and improving ROM (Davies & Nelson, 2015; Rewald *et al.*, 2015). Hydrotherapy must be conducted on a non-slip pool surface, with the water temperature ranging from 24 - 26ºC, and water depth of 120 cm (Fisken *et al.*, 2014). The warmer water temperature increases the extensibility of muscles, thereby making movement easier (Goodwin *et al.*, 2015). The duration of a hydrotherapy session varies from 30 to 40 minutes, with a warm-up and cool-down of 5 minutes each, leaving the remaining time focusing on stretching, increasing muscle strength and endurance and cardiorespiratory fitness (Davies & Nelson, 2015).

It is imperative that therapists be cautious when rehabilitating patients who have co-occurring cardiorespiratory disorders. Aquatic training heart rates are usually 10-20bpm lower than land-based exercises (McArdle *et al.*, 2014). It is recommended that therapists use the Borg's Rate of Perceived Effort Scale (RPE) to measure intensity of effort. Therapists often use balls, pool noodles, foam barbells and other weighted devices to increase the intensity of the effort when performing exercises, as well as to reduce monotony (Fisken *et al.*, 2014; Davies & Nelson, 2015).

Table 1*. EXERCISE PRESCRIPTION GUIDELINES FOR ARTHRITIC PATIENTS

Phases	**Mode (Frequency)**	**Time/Repetitions**	**Intensity**	**Objective**
Phase 1 (weeks 1-8) Hydrotherapy: 3 sessions per week. Warm-up and cool-down (5 min. easy aqua cycling). Progression of exercises can be used for Phase 2 (weeks 9-16). Phase 2 entails 2 hydrotherapy sessions and 2 land-based exercise sessions.	ROM exercises (Every session)	Static ROM exercises held for 10-30 secs. per repetition. Perform 2-4 reps. Active ROM exercises 6-10 reps. Stretch all major muscle groups	ROM exercises are actively performed by the patient. Move within residual ROM adhering to joint arthrokinematics.	To develop or maintain optimal force-couple relationships between agonist & antagonist muscles around joints.
	Cardio-respiratory exercises (Every session)	Duration 10-15 mins. in total. Initially session is divided into 3x5 min. discontinuous sessions. Progression would be to complete 15 mins. of continuous aerobic exercise.	Moderate intensity varies between 50 to 70% of max. heart rate prescribed on present health status. Aquatic training heart rates are 10-20 bpm lower than land-based exercises.	To increase aerobic capacity
	Muscle strength and endurance exercises (Every session)	Session should be discontinuous dividing body into upper and lower limb and core exercises. Patient should perform 10-20 reps. per exercise. Patient should perform 2 sets. Initially, patient can perform one set.	Initially begin with no resistance device, thereafter, progress to aquatic resistance devices.	To increase muscle strength and endurance. To develop and maintain optimal force-couple relationships between agonist and antagonist muscles.
	Proprio-ception (Every session)	2-5 minutes	30 seconds static stalk stand on individual legs Progress to ¼ squat, then ½ squat and eventually ¾ squat on a single leg. Hold each exercise for 30 seconds, repeat twice.	To improve proprioception

Continued

Table 1*. EXERCISE PRESCRIPTION GUIDELINES* *(cont.)

Phases	Mode (Frequency)	Time/repetitions	Intensity	Objective
Land-based exercises Phase 2 & Phase 3 Progression of exercises will be Phase 3. Land-based exercise warm-up and cool-down could be stationary cycling or gentle walking on a treadmill for 5 mins.	ROM exercises (Every session)	Move within residual ROM adhering to joint arthrokinematics. *Practical tip*: Never stretch into painful ROM. Static ROM exercises held for 10-20 secs. per repetition. Perform 2-4 reps. of active stretching. Stretch all major muscle groups.	ROM exercises are actively performed by the patient.	To develop or maintain optimal force-couple relationships between agonist and antagonist muscles around joints.
	Cardio-respiratory exercise (walking, swimming, cycling, jogging. (Every session)	Moderate intensity varying between 50-70% of maximum heart rate based on their health status. Therapist can also use the RPE Scale.	Total duration of aerobic training is 15 mins. Initially perform discontinuous sessions of 10 and 5 mins. Progression will be continuous aerobic training of 15 mins.	To increase aerobic capacity
	Muscle strength and endurance exercises (Every session)	Dynamic strengthening exercises involving isotonic contractions.	Patient should complete 10-20 repetitions of 2 sets. Initially perform one set per exercise. All major muscle groups must be exercised.	To increase muscle and endurance
	Proprio-ception (Every session)	2-5 minutes	30 secs. Static stalk stand on individual legs. Progress to ¼ squat, then ½ squat and eventually ¾ squat on a single leg. Hold each squat for 30 secs. Repeat twice.	To improve proprioception

*Based on a series of evidence-based articles (Nieman, 2000; Nolte & Janse Van Rensburg, 2013; Fisken *et al.*, 2014; Davies & Nelson, 2015; Rewald *et al.*, 2015; Lyp *et al.*, 2016).

Table 1 is a combination of both water- and land-based rehabilitative exercises for arthritic patients. The uniqueness of this proposed exercise therapeutic intervention is in the combination and progression from hydrotherapy to land-based exercises. A further novelty of the programme is the inclusion of a proprioception component. The exact exercise programme prescription will vary for each patient because of their individual needs. However, this programme can serve as a guide. It is recommended that the arthritic patient initially begins with a structured hydrotherapy exercise intervention of three sessions per week that last for 35 minutes for eight weeks. Thereafter, there is progression to two land-based exercise therapeutic sessions and two hydrotherapy sessions for the next eight weeks. Finally, the patients can perform one hydrotherapy session per week and three land-based exercise therapeutic sessions. This gradual progression from water to land-based exercises will foster better exercise therapeutic adherence and maintain benefits derived from the earlier exercise therapeutic intervention.

CONCLUSION

Exercise can positively influence the arthrokinematics of arthritis joints. A sedentary lifestyle is detrimental and impacts the well-being of the patient and the arthrokinematics of joints. Arthritic patients are encouraged to consult a physiotherapist or biokineticist to assist in managing this chronic condition through a therapeutic exercise intervention. An aquatic- and/or land-based exercise therapeutic intervention relives arthritic joint pain and improves ROM, through the exercise-induced physiological lubrication mechanisms.

REFERENCES

AARTS, J.; ALLERDYCE, C.; AMMENWERTH, E.; ANDERSE, M.A. & ANDERSON, C. (2015). Advice on high dose Ibuprofen update. *The Pharmaceutical Journal*, 294(7865). Online.

BJERSING, J.L.; ERLANDSSON, M.; BOKAREWA, M.I. & MANNERKORPI, K. (2013). Exercise and obesity in fibromyalgia: Beneficial roles of IGF-1 and Resistin? *Arthritis Research and Therapy*, 15(1): R34. Online: doi:10.1186/ar4187.

CHEN, Y.; ZHOU, B; WANG, J.; WANG, T.; ZHOA, W.; COA, X.; LU, W. & GUO, X. (2016). Subchondral trabecular rod loss and trabecular plate stiffening precedes articular cartilage damages in osteoarthritis. *Osteoarthritis and Cartilage (Abstracts)*, 24(Supplement 1): S389.

COONEY, K.J.; LAW, R.; MATSCKLE, V.; LEMMEY, A.B.; MOORE, J.P.; AHMAD, Y.; JONES J.G.; MADDISON, P. & JEANETTE M. THOM, J. (2011). Benefits of exercise in rheumatoid arthritis. *Journal of Ageing Research*, ID681640, pp. 14. Online: http://dx.doi.org/10.4061/20 11/681640.

DAVIS, J. & NELSON, R. (2015). Aquatic exercise for pain management in older adults with osteoarthritis. *Therapeutic Recreation Journal*, XLIX(4): 326-330.

DURSTINE, J.L. & MOORE, G.E. (2011). *ACSM's Exercise management for persons with chronic diseases and disabilities* (2nd ed.). New York, NY: Human Kinetics.

ECCLES, J.; FREEMANTLE, N. & MASON, K. (1998). North of England evidence based guideline development project: Summary guideline for non-steroidal anti-inflammatory drugs versus basic analgesia in treating the pain of degenerative arthritis. *British Journal of Medicine*, 317(7157): 526-530.

ELLAPEN, T.J. & PAUL, Y. (2015). Is the mini-squat a fundamental knee rehabilitative exercise? *Austin Journal of Musculoskeletal Disorders*, 2(1): 1013-1014.

ERNEST, F.C.; SANCHEZ-MENDEZ, K.; WILTON, M.; CROWSON, C.S. & MATTERSON, E.C. (2015). Cardiovascular risk profile at the onset of psoriatic arthritis: A population-based cohort study. *Arthritis and Care Research*, 67(7): 1015-1021.

FISKEN, A.; WALTERS, D.; HING, W.; STEELE, M. & KEOGH. J. (2014). Perceptions and responses to different forms of aqua-based exercise among older adults with osteoarthritis. *International Journal of Aquatic Research and Education*, 8(1): 32-52.

FLINT-WAGNER, H.G.; LISSE, J. & LOHMAN, T.G. (2009). Assessment of a sixteen-week training program on strength, pain and function in rheumatoid arthritis patients. *Journal of Clinical Rheumatoid Arthritis*, 15(4): 165-171.

FRENCH, H.P.; CUSAK, T.; BRENNAN, A.; CAFFREY, A.; CONROY, R.; CUDDY, V.; FITZGERALD, M.O.; GILSENAN, C.; KANE, D.; O'CONNELL, P.G.; WHITE, B. & MCCARTHY, G.M. (2013). Exercise and Manual Physiotherapy Arthritis Research Trial (EMPART) for osteoarthritis of the hip: A multicentre randomized controlled trial. *Archives of Physical Medicine and Rehabilitation*, 94(2): 302-314.

GOODWIN, P.C.; QUBAEISSY, K.A.; GREGORY, W.; FATOYE, F. & YOHANNES, A.M. (2015). The effectiveness of aquatic physiotherapy in patients with rheumatoid arthritis: A randomised controlled trial. *Physiotherapy*, 101(1): e464-465.

HART, L. (2006). Are glucosamine and/or chondroitin sulphate effective for knee osteoporosis. *Clinical Journal of Sports Medicine*, 16(6): 528-529.

HOES, J.N.; BUTTINK, I.E.M. & LENS, W.P. (2015). Management of osteoporosis in rheumatoid arthritis patients. *Expert Opinion Pharmacotherapy*, 169(4): 1-12.

HUNTER, D. & ECKSTEIN, F. (2009). Exercise and osteoarthritis. *Journal Anatomy*, 214(2): 197-207.

KIANI, A.; JAHNGIR, S.; JOHN, P.; BHATTI, A.; ZIA, A.; WANE, X.; DEMIRICI, F. & KAMBOH, M. (2015). Genetic link of Type 1 diabetes: Susceptibility with rheumatoid arthritis in Pakistani patients. *Immunogenetics*, 67(5): 277-282.

KIM, I.S.; CHUNG, S.H.; PARK, Y.J. & KANG, H.Y. (2012). The effectiveness of an aquarobic exercise program for patients with osteoarthritis. *Applied Nursing Research*, 25(3): 181-189.

LAW, R.J.; BRESLIN, A. & OLIVER, E.J. (2010). Perceptions of the effects of exercise on joint health in rheumatoid arthritis patients. *Rheumatology*, 49(12): 2444-2451.

LYP, M.; KACZOR, R.; CABAK, A.; TEDERKO, P.; WILOSTOWSKA, E.; STANISLAWSKA, I.; SZYPUTA, J. & TOMASZEWSKI, W. (2016). A water rehabilitation program in patients with hip osteoarthritis before and after total hip replacement. *Medical Science Mentor*, 22(July): 2635-2642.

MANSFIELD, P.J. & NEUMANN, D.A. (2009). *Essentials of kinesiology for the physical therapist assistant* (1st ed.). Maryland, MO: Mosby.

MARIEB, E.N. (2004). *Human anatomy and physiology* (6th ed.). New York, NY: Pearson Benjamin Cummings.

MATOS, P. & JORDAN, P. (2015). Beyond Cox-inhibition: Side effects of Ibuprofen on neoplastic development and progression. *Current Pharmaceutical Design*, 21(21): 2978-2982.

MCARDLE, W.D.; KATCH, F.I. & KATCH, V.L. (2014*). Exercise physiology, energy, nutrition and human performance* (6th ed.). Philadelphia, PA: Lippincott, Williams & Wilkins.

METSIOS, G.S.; STAVROPOULOS-KALINOGLOU, A.; SANDOO, A.; VAN ZANTEN, J.J.; TOMS, T.E.; JOHN, H. & KITAS; G.D. (2010). Vascular function and inflammation in rheumatoid arthritis: The role of physical activity. *Open Cardiovascular and Medicine Journal*, 4(February): 89-96.

MULLER, R.B.; VON KEMPIS, J.; HAILES, S.R. & SCHIFF, M.H. (2015). Effectiveness, tolerability and safety of subcutaneous methotrexate in early rheumatoid arthritis: A retrospective analysis of real-world data from the St. Gallen Cohort. *Seminars in Arthritis and Rheumatism*, 45(1): 28-34.

NIEMAN, D.C. (2000). Exercise soothes arthritis: Joints effects. *ACSM Health and Fitness Journal*, 4(3): 20-27.

NOLTE, K. & JANSE VAN RENSBURG, D.C. (2013). Exercise prescription in the management of rheumatoid arthritis. *South African Family Practice*, 55(4): 345-349.

PINTO, A.J.; MIYAKE, C.N.H.; BENATI, F.B.; SILVA, C.A.; SAILUM, A.M.E.; BORBA, E.; DE-SÁ PINTO, A.L.; BONFA, E. & GUALANO, B. (2016). Reduced aerobic capacity and quality of life in physically inactive patients with systemic lupus: Erythematosis with mild/inactive disease. *Arthritis Care and Research*, 68(12): 1780-1786.

REWALD, S.; MESTERS, I.; EMANS, P.J.; ARTS, C.; LENSSEN, A.F. & DE BIE, R.A. (2015). Aquatic circuit training including aqua-cycling in patients with knee osteoarthritis: A feasibility study. *Journal of Rehabilitation Medicine*, 47(4): 376-381.

RICHMOND, S.A.; FUKUCHI, R.K. & EZZAL, A. (2013). Are joint injury, sport activity, physical activity, obesity or occupational activities predictors of osteoarthritis: A systematic review. *Journal of Orthopaedic Sports Physical Therapy*, 43(8): 515-519.

ROUBENOFF, R. (2003). Exercise and inflammatory diseases. *Arthritis Rheumatoid*, 40(2): 263-266

YOUSIF, A.E. (2008). The role of lubrication mechanisms in the knee synovial joints. *NUCEJ* (*Nahrain University, College of Engineering Journal*), 11(3): 522-535.

ZAMUNER, A.R.; ANDRADE, C.P.; FORTI, M.; MARCHI, A.; MILAN, J.; AVILA, M.A.; CATAI, A.; PORTA, A. & SILVA, C. (2015). Effects of hydrotherapy programme on symbolic and complexity dynamics of heart rate variability and aerobic capacity in fibromyalgia patients. *Clinical and Experimental Rheumatology*, 33(8): 573-581.

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