

# Pilates Based Exercise in Muscle Disbalances Prevention and Treatment of Sports Injuries

Sylwia Mętel, Agata Milert and Elżbieta Szczygieł

<sup>1</sup>*Institute of Physiotherapy Faculty of Health Care,  
Jagiellonian University Medical College in Krakow*

<sup>2</sup>*Department of Physiotherapy, Faculty of Health and Medicine,  
Andrzej Frycz Modrzewski Krakow University,*

<sup>3</sup>*Department of Physiotherapy, Faculty of Motor Rehabilitation,  
The University School of Physical Education in Krakow  
Poland*

## 1. Introduction

The Pilates method has today become more popular than ever. As a form of movement it serves as a basis for fitness, complements sports training and is also one of the methods of physiotherapy. Pilates method combines features typical both for Eastern systems (mind control during exercises, relaxation, increasing of elasticity, movement starting from body center, balance) and Western systems (forming strength, endurance, exercises having both global and local effects). The primary goals in muscle-strain rehabilitation include not only recovery of muscle strength and flexibility but also correction of muscle imbalances. In prevention of sports injuries complementary training regarding body awareness, economical breathing, neuromuscular coordination by executing fluent and precise movement starting from a strong core is suggested. The Pilates based exercise, performed under the supervision of a certified instructor serve these needs and can be part of prophylaxis and kinesitherapy in sport medicine.

## 2. Joseph H. Pilates – A sportsman and kinesitherapist

Joseph Humbertus Pilates (1880-1967) was born in Germany with poor health. The medicine at that time could not offer any antibiotics nor other modern cures. Human health depended mostly on being able bodied. Regular physical exercises were regarded as a prime method of prevention and treatment of many illnesses.

From his parents Pilates learnt how to run sport activities and incorporate physical exercises in the healing process to stimulate it.

In the 19th century there were two main gymnastic systems. The first one was developed by the German Friedrich Jahn. His system derived from ancient Greek gymnastics and was mostly focused on improvement of strength and fitness, which, according to Jahn, were directly connected with well being. The second system, created by the Swede Per Henrik Ling, emphasized rhythm and fluidity of movements. The purpose of these exercises was to

improve the endurance, strength and flexibility of muscles and joints, thereby improving the efficiency of the circulatory system. In Ling's exercise system it was breathing and movement coordination as well as conscious body control during practising were emphasised (Latey 2001). In his early youth J. Pilates gymnastic systems and some common elements can be found in his later invented system of fitness exercises. Since childhood, Pilates was dedicated to practising various physical exercises and developed his interest in human anatomy. As a role model, Pilates took the antic model of beauty, based on the harmonious development of body, mind and spirit. By practising reasonable and balanced sports Pilates became a perfect model for anatomy charts (Mętel & Milert, 2007).

As a young man, Pilates ran many sport activities, e.g. diving and skiing. He was interested in other gymnastic systems (e.g. Yoga) and martial arts (karate). In 1912 he moved to England, earning a living through boxing and as a self-defence trainer. During the World War I he was interned in a prison camp on the Isle of Man, where he organized conditioning exercises for fellow prisoners. It was during this period this Pilates formed his idea on health and healthy lifestyle. Pilates believed that the only way to health is to keep the balance of body and mind, whilst the modern, sedentary lifestyle, bad posture and inefficient breathing were the roots of poor health. Pilates dubbed this philosophy "Contrology", as described in 1934 in his book "Your Health".

Unable to keep practising floor exercises with his fellow camp interns, Pilates used bed springs in resistance exercises, whereby the war wounded could regain their health and fitness while still bed-bound (Sparrowe, 1994, as cited in Latey, 2001). The apparatus Pilates designed during this time served as forerunners of the exercise machines such as „Universal Reformer“ and „Cadillac“ (Trapeze table); spring-based equipment used in Pilates' exercise method.

Pilates returned to Germany after World War I, but in 1926 emigrated to the USA. In New York, together with his wife Clara, he opened his exercise studio. His clients were mostly dancers, with boxers and gymnasts also embracing his method. One of the reasons the method was enthusiastically welcomed by dancers was its similarity to dance in its pursuit of extreme range of movement with precision and control; something a dancer is always attempting to achieve (Latey, 2002). Pilates taught mat and apparatus classes, which required high physical fitness from trainees (McNeill, 2011). In his second book, "Return to Life Through Contrology" (1945), he included selected exercises to follow and practise at home and the development of his philosophy (Latey, 2001). By the time of his death Pilates had extended his system of fitness exercises, describing the principles of correct performance. Pilates stated that his physical exercises could prevent coronary heart disease, increase muscle power and reduce the risk of respiratory ailments. He claimed the efficacy of his method to be scientifically proven, but at the time no such investigation was performed (Lange et al., 2000).

Nowadays, many new Pilates exercises are created based on the elementary ones. They are modified and adapted to various levels of physical fitness, and to the health and age of the practitioner - including those with trauma and elite athletes. In "Traditional" or "Repertory" Pilates, the exercises are vigorous with a fast, dynamic rhythm and even with high level of concentration are not easy to perform properly. They rely on the client having a fairly healthy body with good level of flexibility and to achieve some of the desired positions or range of motion, some muscle groups are obliged to work very hard. This fact contradicts Joseph Pilates' belief in working all the muscles of the body evenly. However, Pilates' ability to keep the rest of an injured body strong and flexible, while allowing the injured body part to heal enables the client to return to work almost as soon as the injury is

repaired. This method of kinesitherapy remains highly relevant today and can be applied to people of all fitness levels (Lately, 2002).

Nowadays, applied Pilates based exercises have been influenced by other body-mind methods and improved by an improved understanding of the human body, new perspectives on illness, advances in medical treatment, new understandings in stress management, developments in psychology and teaching skills. We also support the statement of Lately (Lately, 2002) that updating the principles of the Pilates method has given physiotherapy a new direction, and influenced exercise prescription in many body work fields, including sports medicine. We mainly concentrate on the prevention of injury caused by muscle imbalances and post-acute rehabilitation.

### 3. Methodology and equipment in Pilates' system

Pilates' exercise system can be divided into two categories: floor mat exercises and professional Pilates' devices. Originally, J. Pilates invented a system of stretching and strengthening mat exercises. Later this was extended to include exercises designed using specially designed apparatuses, e.g. Universal Reformer, Cadillac (Trapeze Table), Wunda (Combo) Chair).

The basis of the Pilates system are mat exercises. Postural muscles are mainly strengthened and stretched in low positions, using gravity and the exercised parts of the body. Balanced development of these muscles promotes proper body posture during various activities of daily living and decreases the effects of long-lasting burden, caused by practicing diverse sport disciplines. This makes the Pilates method similar to spine stabilization exercises. It assumes that weakness or fatigue of postural muscles can lead to disturbances of stability in the lumbar spine, which in turn can lead to strain injuries and chronic back pain. A critically important element of this type of training is conscious activation of the profound muscles of abdomen - transversus abdominis (TrA) and pelvic floor muscles (PV), which should fire first for pre-movement stability, and recovering elasticity and eccentric work of superficial muscles.

Exercises on professional Pilates' devices are mainly resistance exercise performed with the aid of springs and pulleys, but also stress relief of certain parts of the body can be achieved. The machines can be customized to the needs of the practitioner. The resistance during the exercise allows movement to be isolated and performed in the proper plane. Additional resistance prevents automatic movements being responsible for injuries. The exercises using professional Pilates' devices can be performed in post-acute state of sports injuries.



Fig. 1. Multidimensional exercise with Pilates circle

Pilates method also utilises small equipment (balls, foam rollers, Pilates circle, balance boards, Thera-bands etc.). They can be used in intralimb and interlimb coordination exercises, or as an element making exercises more attractive. They can also help transferring the learnt exercises to the movement required to run particular sport activities. (e.g. catching or kicking the ball).

In physiotherapy praxis Pilates based exercises are also performed with a gymnastic stick, a gym ladder and a stool. Pilates based exercises using a Swiss ball are also very popular, as is sensoric massage with this tool.



Fig. 2. Sensoric massage with Swiss ball

Exercises are performed from low (lying prone, supine, side-lying, quadruped, sitting) medium and high (kneeling, standing) postures. Low postures ensure better stability during the exercises, used particularly at the early stage of movement learning. Such positions facilitate proper performance of complex movements of upper and lower limbs, aiding concentration on other aspects of exercises (e.g. breathing, precision, flow). In case of complaint such as after injuries or with chronic low back pain, low position stabilisation of the trunk prevents additional unwanted movements that could cause more pain during exercising. For this reason low positions are more often used in early stages of after-injury rehabilitation excluding exercises exerting long lever on the spine. The upper positions can be used at the later stages of rehabilitation. Regardless of the exercise type and position, the movements are performed slowly and deliberately, beginning by correcting the starting position using physical or verbal instructions.

The number of repetitions is usually limited to 5-10. Pilates claimed that the lesser the number of repetitions of the movement performed properly the better the therapeutic effect was. Excessive number of repetitions performed without concentration and awareness can be harmful and lead to injuries. From approximately 500 mat or device exercises that have been developed in Modern Pilates the training programs should be tailored to the practitioner on an individual basis, taking into account his movement abilities and needs (elasticity of tissues, muscle strength and endurance, coordination and concentration ability). The best results can be achieved when practicing one-on-one or in small groups.

The implementation of this method for sports training should start with introducing the so-called pre-Pilates exercises, which allows a moderate degree of difficulty to implement all the principles of this technique from the three-dimensional breathing, slowly adding body alignment, concentration, control, stamina and fluency in performing movement. Moreover,

in modern Pilates based exercise it is not recommended to start each session with an exercise called "The Hundred", as it used to be in traditional Pilates method. According to Lately (Lateley, 2002) this exercise is particularly arduous as an initial exercise, might be extremely dangerous for someone new to the method, and even under supervision can result in severe injury. The authors concur with Lately on this issue.



Fig. 3. Postural alignment in standing



Fig. 4. Stability and endurance training: core muscle activation with limbs exercises

#### 4. Body-mind exercise system

The purpose of the system of fitness exercises developed by Pilates is to develop harmony of body, mind and spirit by improving muscle strength and increasing the elasticity of active movement structures. The movements are carried out slowly and fluently with focused attention. These exercises are referred to as a "body-mind exercise system". Other such systems include also Yoga, Tai Chi and Feldenkreis' method.

"Body-mind exercises" is not the name of the exercise, but rather a description of how an exercise should be performed. Their common features are: mind control during exercises, relaxation of muscles and joints not involved in exercise movement, and maintaining muscles' physiological elasticity, with movement starting from body centre.

Understanding one's individual optimal postural alignment (neutral posture) will allow economy of movement, a natural flow of compensatory patterns, so that no muscle is

overworked or misused, without aiming for perfect symmetry. Pilates explained the balance of body and mind as the conscious control of all muscular movements of the body. It is the correct utilisation and application of the leverage principles afforded by the bones comprising the skeletal framework of the body, a complete knowledge of the mechanism of the body, and a full understanding of the principles of equilibrium and gravity as applied to the movements of the body in motion, at rest and sleep. Concentration and awareness is one of the fundamental principles of Pilates' system. It determines movement in a particular muscle group. It is very important, especially when other sectors of locomotors apparatus do not act properly or are not in natural alignment because of trauma or sport injury. That is why Pilates' system is nowadays recognized as a relatively safe alternative for intensive aerobic or weight bearing exercises. (Latey, 2001, as cited in Latey, 2002).

Awareness of the performed movement improves its efficiency and quality of movements. According to the original assumptions of the Pilates' system it requires at least an elementary knowledge of biomechanics and functional anatomy by the practitioner. It facilitates the process of learning new movement patterns, especially those to be transferred into functional tasks such as walking, reaching, lifting and other daily living or sport activities (Lange et al., 2000).

Focusing on the therapeutic movement, particularly in the case of sport injuries helps to avoid errors in repeating the exercises without therapeutic supervision. Proper learning of movement can be also achieved with the help of hands-on guiding, assisting correct movement (touch can improve muscle engagement and relaxation). Verbal cues also play a very important role in increasing awareness of the therapeutic movement being performed and learnt. This applies particularly in the case of a limited amount of information such as typically used with elderly or stroke patients (Lange et al., 2000; Latey, 2000). Verbal cues of the Pilates based exercise instructor as well as his tactile stimulation (hands-on) aim to motivate the exercisers to increase the focus on how to perform movement and maintain the desired body position, so that sensorimotor integration is stimulated. Moreover, connecting the mind and body requires the exercising person to tune into their bodily sensory systems.



Fig. 5. "Hands on" for body alignment execution

Touch can improve muscle recruitment, a client's awareness and also introduce better body biomechanics and relaxation. Awareness of the sensations, touching the muscles and joints

helps to focus concentration. Awareness of the body also assists in reducing overwork, strain and tension. Sportsmen particularly need awareness of their body, particularly the muscular sensations, so as to direct mental and physical efforts efficiently. Attending to the feedback from the proprioceptor system makes the individual aware of what is being done. Precision assists coordination; this is the practical application of focused awareness.



Fig. 6. Manual stimulus for increasing body awareness and desired muscle recruitment

## 5. “Powerhouse” – The strong core

Popular weight lifting in a gym studio typically focuses on improving muscle strength by shortening the muscles; the complex role of the supporting muscles is ignored. However, as the body lengthens, the diagonally opposed supporting muscles also have to work well. Stretching the muscles is an important part of sport training and in order to regain muscle balance, with the muscles lengthening and working at the same time, eccentric muscle contractures with proper support from stabilizing deep muscles and the body centre is needed.

Major emphasis in the Pilates concept should be placed upon the muscles forming ‘powerhouse’- the body centre. Joseph Pilates himself never set down in writing what the exact parameters of the powerhouse were and there does not seem to be exact agreement amongst the master teachers of Pilates today. In a recent legal decision, the ability to trademark the name Pilates, and consequently the sole right of certification of Pilates instructors was lost. This means that there is no longer one certifying or governing body that determines exactly what the Pilates method is or is not. As a result, the Pilates based exercise, along with the underlying biomechanical basis, has been diverging greatly in recent years. There are now many techniques within the Pilates world, some adhering strictly to the system of exercises developed by Joseph Pilates, and others that are incorporating changes into this system.

The powerhouse is the core centre of the body from which peripheral muscle actions are carried out. The idea of centring is to create not only a strong structural powerhouse, but also a flexible one. Indeed, Joseph Pilates had the following maxim on his business card: “A man is only as old as his spine is inflexible”. Profound muscle strengthening is a very important supplementation for training in various sports disciplines where big, superficial

muscle groups are mainly reinforced. Skipping profound muscles in strength training leads to imbalance, which increases the risk of trauma, and often is the reason for serious sport injury. It is suggested that treatment of muscle imbalances should start with exercises that isolate specific core muscles and then progress into functional activities or complex sports movements where these muscle should act in synergy to stabilize the lumbo-pelvic region.

Pilates method of body conditioning may be generalized to have three major effects upon the powerhouse. First, Pilates affects the posture of the pelvis, which results in postural changes to the lumbar spine. Second, it works directly upon the musculoskeletal structure of the spine (the lumbar spine in particular) by strengthening, stretching, and lengthening the spine. Third, Pilates affects the structural integrity or tone of the abdomino-pelvic cavity as a whole. The posture of the pelvis largely determines the posture of the spine. The spine sits upon the base of the sacrum; therefore, any change in the sagittal posture of the pelvis will change the level of the base of the sacrum. The level of the base of the sacrum will in turn affect the curve of the lumbar spine. However, once the base of the sacrum is uneven to any degree, the spine must have a curve in it to compensate. This curve is necessary to eventually create a level base for the head to sit upon. This righting mechanism to create a level base for the head is necessary to place the eyes and the labyrinthine receptors of the inner ear on a level plane, this being necessary for proper static and dynamic proprioception of our body.



Fig. 7. Execution of strong core with body alignment before and during movement

One of the major emphases of Pilates is to address the posture of the pelvis by addressing the musculature of the pelvis. Pilates further corrects this imbalance by placing a strong emphasis on stretching the low back musculature. In this manner, Pilates aims to create a neutral pelvis, and thereby create a healthy lumbar lordosis. (Muscolino & Cipriani, 2004 as cited in Selby, 2002; Siler, 2000; Winsor, 1999).

## 6. Breathing in Pilates

Body posture has an impact on the functioning of the entire human organism. There are reasons to believe that correct posture is a prerequisite for correct breathing patterns (Fiz & Gnitecki, 2008). Deficient respiratory capacity reduces the amount of oxygen delivered to body cells, which hampers both physical and intellectual performance. Symptoms of oxygen



deficiency include headache, vertigo, lack of appetite as well as concentration and memory malfunctions. Lower oxygen levels have a negative impact on muscles, which are likely to work deficiently under such circumstances and tire faster, which can lead to general fatigue and listlessness. The body tries to compensate for the oxygen loss, involving additional breathing muscles in the respiratory process, which then requires higher energy consumption and reduces its efficiency. The entire body is involved in breathing. During respiration, the functioning of the breathing muscles changes the dimensions of the chest. Shoulders and particular backbone sections are also part of the breathing cycle. Any immobilization, disfigurement, pain, lesions or developmental defects of the chest, as well as breathing muscles palsy can have important consequences for mobility and thus reduce the lungs' ventilation range. It needs to be stressed that most pathological processes, not only such severe ones as pneumonia, bronchitis, chronic obstructive pulmonary disease and heart failure, but also those of lesser clinical importance, including meteorism, intercostal nerve pains, or shoulder neuralgia clearly change the breathing mechanics (Dyszkiewicz et al., 2003). Changes in posture and its incorrect models related to the synchronized functioning of the muscles of the neck, upper body, abdomen, shoulders and pelvis are crucial for breathing (and in consequence for chest mobility). Other remote factors, seemingly unrelated to chest biomechanics, include the impairment of the motoric function of the lower extremities and the backbone, with a modification of the movement patterns. Research carried out by Szczygiel (Szczygiel et al., 2010) on healthy people indicated that even momentary slightly forced posture distortions can have a strong impact on breathing parameters. The research was an attempt to specify the plane in which posture distortions most severely influence the functioning of the respiratory system. Results show that the body arrangement most likely to lead to a reduction of the VC is posture with counter-lateral head, shoulder and hip rotation. The position responsible for the greatest reduction of other factors (VC- Vital Capacity, FEV1- Forced Expiratory Volume in One Second, MEF75- Maximal Expiratory Flow at 75% of Force Vital Capacity, MEF50- Maximal Expiratory Flow at 50% of Force Vital Capacity, MEF25- Maximal Expiratory Flow at 25% of Force Vital Capacity and PEF- Peak Expiratory Flow) was frontal stooping. Positions with sagittal plane changes had the smallest effect on breathing mechanics. Therefore, optimum conditions for breathing require an axial arrangement of particular body segments.

According to Joseph Pilates "breathing is the principal art of life. Our life depends on it. Millions have never learned the art of correct breathing." From the day we were born, we have been breathing unconsciously, without worrying if our breathing is correct.

Correct coordination of breathing with a particular exercise is the rule of thumb applied while teaching the Pilates method. Correct breathing improves blood oxidation, brain function and movement control.

In Pilates, costal-diaphragmatic breathing is used, accentuating protracted exhalation with simultaneous drawing of the navel closer to the spine. While inhaling, the chest expands in three planes, and while exhaling, abdominal oblique muscles become involved. This is called "lateral breathing". Lateral breathing causes the chest to expand, and the air penetrates the back and lateral parts of the chest. This stimulates intercostal muscles, allowing them to expand and making the upper body more agile.

Normally, our breath is too shallow, and stress compounds the problem, making our breathing faster and even shallower (Rakowska, 1990). Women tend to breathe with the tip or the upper part of the lungs, raising their shoulders and the upper body. Men are more likely to breathe using their diaphragm, making their abdomen expand with every breath.

An important element of the Pilates method is being able to expand the ribs laterally, which helps you to draw in your abdomen, at the same time relaxing the upper body. While accentuating the axial arrangement of the body, the method ensures the optimum conditions for the respiratory system and helps to stabilize the backbone. This is of crucial importance for people practicing sports, who are likely to adopt forced body posture. This increases the risk of overload changes in the body, and hampers the functioning of the respiratory system (Bliss et al., 2005). Unlike other exercises based on passive breathing, the Pilates breathing method involves active respiration. It activates outer intercostal muscles and abdominal muscles. The most efficient muscle participating in breathing out, and thus in increasing the pressure in the abdominal cavity is the transverse abdominal muscle (Zocchi et al., 1993).

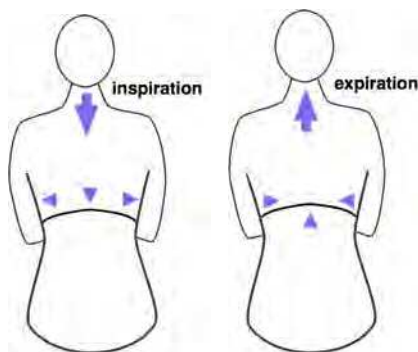


Fig. 8. Pilates method breathing

Deep breathing is an important element of exercise optimisation. The fact that the basic movements in the exercise are made while breathing out, sets the method apart from others. In addition, prolonging exhalation helps to counteract the occurrence of undesirable tension (protracted additional respiratory muscle cramps) and ensures greater stabilization in the most difficult phases of the exercise. While considering reports on the effectiveness of the method, an issue that must be mentioned is the case of diaphragm rupture while breathing deeply using the Pilates method (Yang et al., 2010). Cases of such spontaneous diaphragm rupture, without prior antecedents in patients, are extremely rare. They may occur e.g. with abrupt coughing. They account for ca. 1% of similar diaphragm problems (Gupta et al., 2005). The causes are related to a rapid increase in abdominal pressure. Weighted against the benefits of the method, such cases seem to be of marginal importance.

Meanwhile, both scientific magazines and popular science publications frequently look at bronchial asthma in athletes. Statistics regarding asthma indicate that it occurs more frequently in athletes than in the general population (Weiler et al., 1998). This topic is quite controversial. On the one hand, it is suggested that prolonged intensive training may lead to the development of bronchial asthma (Weiler et al., 1998) and (Helenius et al., 1998). At the same time, the issue of the use of medicines by asthmatic athletes in the context of pharmacological doping is raised. In light of the above, the Pilates breathing method may be a valuable element of physical training. There is no doubt that optimum breathing allows for longer and more intensive training without running the risk of excess fatigue. The asthma debate is exhaustively discussed in an article by Wroński. The author believes that Pilates breathing exercises can be used to complement drug therapy in children and young people with bronchial asthma (Wroński & Nowak, 2008).

## 7. Muscle imbalances and Pilates practising by sportsman

The muscle balance in any joint is determined by the ratio of torques between agonist and antagonist muscle groups. The coordination of movements depends on the coordinated actions of muscles on the opposite sides of a joint. This prevents injuries of muscles, tendons, and joint elements during fast movements. The deficiency of strength in one muscle or muscle group can lead to imbalance in the joint actions, which in turn can cause traumas of muscles and joints due to the anomalous distribution of mechanical stresses and strains. (Pontaga, 2003) The terms muscle balance or imbalance do not refer to equal or unequal torque values, but to the balance between the torque ratios of agonistic and antagonistic muscle groups (Gioftsidou et al., 2008). There is a failure of the agonist-antagonist relationship and to their balance between the torque ratios. Muscle imbalances resulting in overloaded movement apparatus can result from frequent repetition of movement patterns specific to the sport's discipline. Static overload refers to the maintenance of posture of the body for a longer period of time such as the trunk flexion in cycling, downhill, speed skating, alpine skiing. Dynamic overload can result from forced movement which is typical of the discipline, leading to the development of muscle imbalances. Because the human physiological motor activities take place in the area of the force of gravity to align the existing muscle imbalances Pilates method offers exercises in various starting positions with multidimensional movements in which skeletal muscle are activated in a manner conducive not only to development of their strength but also endurance, flexibility and neuromuscular coordination. Therefore, this system, with appropriate supervision and adjustment of the degree of difficulty of the exercises to be performed without losing the flow of movement and dynamic stabilization of the deep muscle system appears to be appropriate in the eradication of unwanted muscle imbalances. Recent studies hypothesized a common muscle imbalance pattern of weakness in gluteus medius and tightness of the iliotibial band in chronic musculoskeletal pain syndromes in the lumbar-pelvic-hip area such as chronic low back pain. Investigators categorized muscles, based on their primary functions, as "phasic" or "postural", and indicated that in response to dysfunction or overuse, the phasic muscles tend to be inhibited or weakened; while the postural muscles tend to develop higher tone and ultimately shorten. [Jull&Janda, 1987, Janda 1992,1993 as cited in Arab&Nourbakhsh, 2010] Tight muscles are activated more readily during movement patterns and become overactive. Once the phasic and postural muscles are no longer activated in balance, they are unable to protect the body's joints from the effects of gravity. (Page, 2005)

In this classification, the gluteus medius; primary muscle for hip abduction, is categorized as phasic and the tensor fasciae latae and iliotibial band the synergist muscle, is categorized as postural muscle. It is speculated that the iliotibial band shortness in patients with low back pain is a compensatory mechanism following hip abductor weakness. (Jull&Janda, 1987 as cited in Arab&Nourbakhsh, 2010). Controversial results have been reported in the studies which examined the relationship between hip abductor strength and the iliotibial band syndrome in runners. Some researchers concluded after conducting a study with runners with the iliotibial band problems that strengthening of the hip abductors has been recommended for symptom improvement in subjects with the iliotibial band dysfunction (Fredericson&Weir, 2006, MacMahon et al. 2000 as cited in Arab&Nourbakhsh, 2010) while others in contrast (Grau et al., 2008 as cited in Arab&Nourbakhsh, 2010) concluded that weakness of hip abductors does not seem to play a role in the etiology of the iliotibial band

syndrome in runners. Some reports have also demonstrated an association between LBP and hip abductor muscle weakness.

Considering the above reports and the promising results of research on the effects of Pilates exercises to reduce chronic low back pain seems to be a reasonable recommendation to use Pilates techniques for athletes with low back pain. Note, however, that the scientific evidence demonstrating the efficacy of this method in the treatment of back pain are incomplete. Modern group sports such as soccer is marked by a faster speed of play than in the past, and this inevitably translates into an increase in the intensity of practice sessions. This may justify an increase in the percentage of muscle strains occurring during practice.

We suggest an assessment whether it is observed that a player's muscle imbalances is only an adaptive response to the athlete's body to the demands of the discipline and is tolerated by him, or results of biomechanical changes in articular' trajectory caused by the development of the areas in the body with reduced resistance to overload (*locus minores resistanci*). It is worth to check if after previous trauma protective mechanisms of the damaged area have extinguished and not result in persistently maintaining the stiffness and the development of undesirable tissue compensation. Because such mechanism may change a whole myofascial chain and neuromuscular coordination it is possible that pain may also occurs in a place located far away from the primary pathology. Also, persistent pain or fear of its occurrence may lead to changes in motor programs resulting in the development of muscle imbalance syndromes, particularly in muscle tone and their flexibility. For example, examining the strength and elasticity of muscles of lower limbs, often stated gluteal muscles weakness and their function of the hip' extension is overtaken by hamstring muscles which results in excessive tension and shortening. In turn, the weakening of the abductors and external hips' rotators, usually cause the hypertone in the area of iliotibial band. Certain muscles in the human body are especially subjected to strain traumas, for example, the posterior muscle group of thigh. The simultaneous extension of the hip joint and flexion of the knee stretch the posterior muscle group of thigh and, if the movements are very fast and forceful (sprinting, bobsledding, jumping, and other athletic sports), these muscles can be injured. (Pontaga, 2003). In the study analysing muscle injuries suffered in Italian major-league soccer team during the period 1995-2000 it was found that among the overall injuries, muscle accidents were the most frequent, representing 30% (103 cases), followed by contusions (28%), sprains (17%) and tendinopathies (9%). Proposed causes of muscle strains were: lack of training, insufficient warming up, excessive fatigue, strength imbalances, flexibility deficiencies, muscle weakness and insufficient rehabilitation. (Volpi et al., 2004)

A study of the role of eccentric muscular work in the development of muscle strains found a residual eccentric-strength deficit in sprinters with a history of hamstring injury compared to runners with no injuries. (Jonhagen et al. 1994 as cited in Volpi et al., 2004)

Factors increasing the risk of developing acute muscle injuries, include decreased muscle strength, mainly eccentric muscle strength and muscle imbalance (decreased eccentric work of antagonist to concentric work of agonist (Schwellnus, 2004 as cited in Gioftsidou et al., 2008). In running and kicking there is an important eccentric activation of thigh muscles. When decelerating in running, the hamstrings act eccentrically to slow extension at the knee, and the quadriceps act eccentrically to control the lowering of body weight when athletes approach a stop. In kicking muscles, activation follows "the soccer paradox" meaning that

flexor activity is dominant during extension and extensor activity dominates during flexion. Quadriceps activity is greatest during the loading phase when it is antagonistic to the movement and hamstrings are most active during the forward swing when they are antagonistic to the movement (Volpi et al., 2004).

There is no knee extensor activity immediately prior to ball contact. The eccentric activation of knee flexors reduces the angular velocity at the knee. Such a mechanism protects the knee from hyperextension, but it is extremely stressful for hamstrings. (Robertson&Moshe,1985 as cited in Volpi et al., 2004). Electromyography studies have confirmed hamstring peak activity near the time of ball contact. (Wahrenberg et al., 1978 as cited in Volpi et al., 2004)

Recuperation of flexibility (Kujala et al., 1997 as cited in Volpi et al., 2004), amelioration of muscle strength (Worrell, 1994 as cited in Volpi et al., 2004) and correction of muscle imbalances (Welsch, 1988 as cited in Volpi et al., 2004) represented the primary goals in muscle-strain rehabilitation. It is important to underline that prevention of recurrences, not speed of recovery, is the primary goal in muscle- strain rehabilitation. It is suggested that athletes who have suffered a muscle injury must never give up eccentric work for the rest of their careers (Volpi et al., 2004).

As Pilates method offers different eccentric exercises for trunk and leg muscle e.g. rolling the spine in different position with or without using the equipment or tools (Swiss ball, Thera-band) in our opinion this method can be suggested as a complementary sport training. Elasticity of the leg muscles, especially hamstrings, iliopsoas, quadriceps, hip rotators, plays very important role in maintaining the proper body posture both in rest and in motion. Weakness and contractions of this muscles lead to improper pelvic alignment in standing position, and consequently in spine and total body. In athletes practicing e.g. cycling, leg muscles work intensively in contracting position, while complementary Pilates training provides the eccentric exercises.

It is indicated that fatigue of the shoulder complex muscles, which may occur in overhead athletes or workers with regular exposure to overhead work, is proposed to be a neuromuscular alteration that contributes to shoulder pathology. Acute muscle fatigue may create short-term muscle force imbalances and disrupt normal synergistic activation of the muscles at the shoulder region. These activation imbalances may in turn result in the scapulothoracic kinematic alterations. Acute fatigue of the serratus anterior may be particularly problematic as this muscle has been noted to be the primary contributor to both normal three-dimensional scapula rotations and scapulothoracic stability. In addition, the serratus anterior is considered to be one component of several muscle synergies at the shoulder complex and its fatigue may alter the balance of these synergies. (Szucs et al., 2009)

Precise control of movement at the shoulder complex during upper extremity use is considered critical to the health of the shoulder region. In Pilates based exercise it is strongly recommended to keep scapulas in position of "soft V" at starting positions so the intention is to voluntarily "fix" the scapula in the position of posterial depression. It is generally accepted that serratus anterior and the trapezius (upper and lower) should work with proper timing to provide normal, three-phases humero-scapular rhythm. In first phase upper trapezius should be relaxed and scapula fixation should be provide by lower trapezius. In second phase scapula external rotation is achieved by the activation of serratus anterior and at last upper trapezius with other scapula's elevators need to fire to lift the scapula up. (Horst, 2010)



Fig. 9. Push-up exercise on Swiss ball, starting position without “locked elbows”



Fig. 10. Push-up exercise on Swiss ball , movement with activation of strong core

It was found that the upper trapezius and serratus anterior are under differing cortical control mechanisms, with trapezius but not serratus demonstrating both contralateral and ipsilateral responses to cortical magnetic stimulation. Increased upper trapezius tone and constant readiness to activate disturbs the humero-scapular rhythm and is also an indication of fatigue or compensation of serratus anterior. As muscle fatigue can be a central phenomenon as well as a peripheral phenomenon, the upper trapezius may have been recruited differently during or after the task. (Alexander et al., 2007, Hunter et al., 2006 as cited in Szucs et al., 2009) It is ball, important that performing Pilates Push-up, which is an exercise in close kinematic chain, serratus anterior muscle should be activated rather than a dominant role of upper trapezius muscle which can be achieved by the alignment of spine, unlocked elbow joints, lower - costal breathing and touching stimulus of an instructor during execution of an exercise.

The Push-up exercise has been recommended as a rehabilitative exercise for individuals with shoulder pathology because it strongly activates serratus anterior while minimizing upper trapezius co-activation (Ekstrom et al., 2005, Lear&Gross 1998, Ludewig et al., 2004 as cited in Szucs et al., 2009). Using this task as a rehabilitative exercise may be too strenuous for most patients, but it may have potential as an assessment tool to help determine the success of serratus anterior strengthening and endurance training or the readiness for return to high demand overhead work. (Szucs et al., 2009)

The results of the controlled study with 19 participants show that a 12-week long Pilates training program was effective in improving core strength and posture (exercising subjects showed smaller static thoracic kyphosis during quiet standing) as well as certain aspects of

scapula and upper trunk displacement during a shoulder flexion task. As deficits in neck-shoulder biomechanics have previously been associated with symptoms in the neck-shoulder region, these results could support the use of the Pilates method in the prevention of neck-shoulder disorders. (Emery K., 2010)

In our opinion Pilates can be recommended as a complementary exercising method for many sports discipline to reduce muscle imbalances, increase body awareness, sensomotoric coordination, economical breathing, body alignment, precision and fluency in movement however deep understanding and proper implementation in the practise the main Pilates principles under close supervision of certified and experienced Pilates instructor is needed.

## **8. Pilates method in evidence based medicine**

Current state of neurophysiological and biomechanical knowledge has caused that classical Pilates technique evaluated into Pilates based exercises which are recommended for use by people of varying age and physical proficiency. We conducted database searches (SPRINGER LINK, SCIENCE DIRECT, EBSCO HEALTH SOURCE, MEDLINE, PUBMED, COCHRANE, EMBASE) up to the June 2011 to investigate the application and effectiveness of this method using the key word "Pilates".

### **8.1 Pilates based exercise programs effects in different age population**

Rogers and Gibson explains that studies concerning Pilates method primary concentrated on its effects in rehabilitation or to increase specific component of movement – such as tennis serve velocity (Sewright, 2004 as cited in Rogers&Gibson, 2009), leaping ability (Hutchinson 1998 as cited in Rogers&Gibson, 2009) or muscular strength and endurance in specific population.

In a controlled experiment of Rogers and Gibson with healthy, young objects (n=28) in which novice practitioners (n=9) participated 3-times a week, 1-hour session in 8-week traditional mat Pilates program, it was concluded that in experimental group body composition, muscle endurance and flexibility improved compared to participants of university wellness centre forming the control group. (Rogers&Gibson, 2009)

In the controlled study of Siqueira Rodrigues with 52 elderly females, 27 persons formed the Pilates group participating in Pilates exercises twice a week for eight weeks. The researchers concluded that the practice of the Pilates method can improve the functional autonomy and static balance of elderly individuals (Siqueira Rodrigues et al., 2010)

In pilot study with 7 older adults who participated in a novel Pilates inspired exercise program specifically designed to improve balance in an upright position, referred to as postural stability it was indicated that the effect in relation to static balance can be a consequence of postural stability, reached by the harmony of opposing muscle groups. (Kaesler et al., 2007)

Siqueira Rodrigues introduce Pilates as a method consisting of a physical exercise that uses resources such as gravity and the resistance of springs, either to resist or assist movement execution (Gagnon, 2005 as cited Siqueira Rodrigues et al., 2010). It aims to prevent automatic movements, which are responsible for unwanted muscle activity that can cause injuries (Petrofsky et al., 2005 as cited in Siqueira Rodrigues et al., 2010). Siqueira Rodrigues also indicates that Pilates method has been studied in relation to its positive effects on posture (Blum, 2002 as cited in Siqueira Rodrigues et al., 2010), pain control (Gladwell et al.,

2006 as cited in Siqueira Rodrigues et al., 2010), improved muscle strength (Schroeder et al., 2002 as cited in Siqueira Rodrigues et al., 2010), flexibility (Segal et al., 2004 as cited in Siqueira Rodrigues et al., 2010), and motor skills (Lange et al., 2000 as cited in Siqueira Rodrigues et al., 2010).

The positive influence of Pilates exercise on dynamic balance and personal autonomy in healthy adults was assessed in the controlled study with the 17 participants of 10 Pilates-based exercise sessions performed on a Reformer and including a tall arm series, open leg rocker, leg press series and tall kneel arm series. After the Pilates training significant change in dynamic balance was found in the Functional Reach Test, while control, non-exercising group (n=17) demonstrated no significant change. These findings suggest that Pilates-based exercise may be a useful tool for clinicians and trainers to incorporate with their patients and clients who are looking to improve their dynamic balance and also benefit athletes who are seeking small gains to improve performance through precise, controlled movements. (Johnson et al., 2007)

Some authors indicates that Pilates encouraged the importance of proprioceptive stimulation for motor learning improvement using the powerhouse exercise (transversus abdominus, obliques, and multifidi muscles) and repetition of correct movement to achieve the training standard, leading to a better motor performance and less risk of injuries. (Anderson & Spector, 2000 as cited in Siqueira Rodrigues et al., 2010)

An observational study was conducted to assess and compare the contraction of the transversus abdominis muscle among 36 healthy females (mean age 36.2) trained in Pilates, traditional abdominal curls and a control group. To indirectly measure contraction of the transversus abdominis muscle and to monitor lumbar-pelvic stability, a stabilizer pressure biofeedback unit (Chattanooga Group Inc.) was employed and a tester, blinded to group category, conducted the measurements. For the lumbar-pelvic stability test, only 5 (42%) Pilates group subjects passed this test, with all others failing this test, leaving 14% overall who were able to stabilize the lumbar-pelvic area. The authors concluded that females who train in Pilates may be better able to recruit and utilize their deep abdominal muscles and stabilize the pelvic area compared to those not trained in Pilates. (Herrington & Davies, 2005)

In the controlled, experiment with 34 pain-free health club members with no Pilates experience who were randomly assigned to an unsupervised twice weekly of eight weeks Pilates mat exercises or strength training it was concluded that transversus abdominis activation increased following a programme of unsupervised Pilates mat exercises that is practical and requires no special equipment, however, there was no change in abdominal muscle activation during functional postures. The researchers suggested that supervision of exercises and progression to more functional exercises may be required to increase functional abdominal activation. (Critchley et al., 2011)

Performing Pilates exercise might prove to be a useful means of increasing activity and thereby curbing the obesity epidemic of female teenagers. It was proven in a randomised, controlled study that 4 weeks long physical training with the Pilates technique lowered the BMI percentile of 10- to 12-year-old girls. (Jago et al., 2006)

## **8.2 Pilates method and low back pain**

Two systematic reviews of all controlled clinical trials of Pilates to treat low back pain were recently conducted. In the most recent review the search strategy was filled up to May 2010



and generated a total of 199 references, of which 51 were considered potentially relevant. Study quality was assessed using the Oxford scale. Four eligible randomized controlled clinical trials (n = 4) involving Pilates for the management of low back pain were included. They originated from the United Kingdom (Gladwell et al., 2006 as cited in Posadzki et al., 2010), the United States (Head et al., 2006 as cited in Posadzki et al., 2010), Italy (Rydeard et al., 2006 as cited in Posadzki et al., 2010) and Canada (Vad et al., 2007 as cited in Posadzki et al., 2010). Although some of the authors of the reviewed studies conclude that Pilates yielded better therapeutic results than usual or standard care, the findings of this review suggest that the evidence available for its clinical effectiveness is inconclusive. (Posadzki et al., 2011)

The second systematic review published this year with meta-analysis aimed to compare pain and disability in individuals with persistent nonspecific low back pain who were treated with Pilates exercises compared to minimal or other interventions based on 7 randomized controlled trials. In conclusion they stated that Pilates-based exercises are superior to minimal intervention for reduction of pain in individuals with nonspecific low back pain. However, Pilates-based exercises are no more effective than other forms of exercise to reduce pain. In addition, Pilates exercises are no more effective than minimal intervention or other exercise interventions to reduce disability related to chronic low back pain. (Lim et al., 2011)

These two systematic reviews show that the evidence base for Pilates method effectiveness in treatment of chronic low back pain remains scarce and therefore larger and better-designed clinical trials are needed.

### **8.3 Pilates based exercise in post-surgery rehabilitation**

Pilates practice applied in post-surgery rehabilitation were found in conference review, preliminary report and case study article.

It is possible to use different tools and special equipment when incorporating Pilates based exercise into treatment process. In the review which aims to establish an evidence-based approach to the postoperative rehabilitation of the knee following anterior cruciate ligament reconstruction, arthroscopic meniscectomy and meniscal repair surgery exercises performed with the use of Pilates Reformer machine were investigated.

The authors emphasized that there has been a gradual move away from traditional methods towards accelerated rehabilitation programs for anterior cruciate ligament reconstruction following the observation that patients who had been noncompliant with traditional rehabilitation progressed more rapidly. (Decarlo et al., 1992, Shelbourne et al., 1990 as cited in Atkinson et al., 2010) They claim that accelerated rehabilitation programs, which aim to overcome the common post-surgical problems of prolonged knee stiffness, anterior knee pain, difficulty gaining full extension and delays in the strength recovery, maintaining knee stability may include following types of exercise: closed and open kinetic chain, eccentric, concentric, isometric, isokinetic, plyometric, sport-specific and Pilates method. The Pilates Reformer machine exercises allowing the patient to be positioned in such way as to help to remove gravity from the equation and other equipment exercise for core stability strength and co-ordination are included after the 4-week in post-operative anterior cruciate ligament reconstruction protocol. The author indicates that additional use of Pilates Reformer machines according to the principles of the Australian Physiotherapy and Pilates Institute may allow for earlier progressive load

bearing and introducing squatting or lunging activities in treatment process. The theory behind this approach is to introduce consistent motion and defined joint ranges early in the rehabilitation period, using zero-gravity spring-based resistance. This allows for exact functional patterns and muscle memory to be retrained and thus, when the patient is ready to weight bear into a squat or lunge, the motion has already been learned. Though there is currently little scientific data to support this new approach, it may shorten rehabilitation by as much as 4 weeks, with the largest effect seen within the first 2 months. The authors of the survey proposed at the 3-month post-operative review functional exercise for neuromuscular coordination and also Pilates exercises for core stability and strength with the application of all equipment. (Atkinson et al., 2010)

In a preliminary report with 38 participants Pilates method was introduced into modified exercises programme developed to account for the postoperative precautions and needs of total hip and knee arthroplasty. At 1 year follow up, review of patient charts and follow up telephone calls revealed; 25 patients were extremely satisfied and 13 were satisfied with their outcome and use of Pilates in their rehabilitation. From these observations of a small number of patients it was concluded that this technique can be utilized without early complications, however, further studies are necessary to confirm its utility and safety. (Levine et al., 2009)

Other report which documented the use of the Pilates method in medical rehabilitating of postsurgical patients and for recuperation of musculoskeletal condition was case study concerning treatment of scoliosis of adult woman who had progressive severe low back pain. She had worsened over the years after her surgery and had prevented her from activities such as carrying her son or equipment necessary for her job as a photographer. The patient was provided a series of Pilates exercises used to overcome her chronic habituation and muscle weakness. It was concluded that addition of Pilates based exercise to therapy can be useful to care for patients with chronic low back pain and deconditioning (Blum, 2002).

#### **8.4 Pilates based exercise in specific disorder treatment**

In a randomized clinical trial comparing pelvic floor muscle training to a Pilates exercise program for improving pelvic muscle strength 62 women with little or no pelvic floor dysfunction were randomized to Pilates or a pelvic floor muscle-training. The results of the study demonstrated only the feasibility of a Pilates exercise program for strengthening the pelvic floor muscles with the important note that these findings are only relevant to those women who can "find" their pelvic floor muscles however are encouraging and may eventually lead to widespread use of Pilates-based exercise programs to treat and prevent pelvic floor dysfunction. (Culligan et al., 2010)

In a randomised, controlled trial with 52 breast cancer patients and also in one pilot study of with 4 women who had undergone axillary dissection and radiation therapy for breast cancer it was concluded that Pilates exercises are safe and efficient for women with breast cancer but there is a need for further studies to confirm these statements. (Eyigor et al., 2010, Keays et al., 2008)

In a randomized, prospective, controlled, and single-blind trial with 55 participants the effects of Pilates on pain, functional status, and quality of life in patients with ankylosing spondylitis were investigated. Pilates exercise program of 1 h was given by a certified trainer to 30 participants of experimental group 3 times a week for 12 weeks. It was the

first clinical study designed to investigate the role of Pilates method in ankylosing spondylitis treatment with a conclusion that this exercise technique is as an effective and safe method to improve physical capacity in ankylosing spondylitis patients. (Altan et al., 2011)

## 9. Conclusion

Studies concerning effects of performing Pilates based exercise suggest its beneficial influence on body posture, pain control, muscle strength, endurance, flexibility, body composition, static balance, functional autonomy, motor skills and specific component of sport activities. There is an increasing number of scientific reports suggesting application of Pilates method into modern, mind-body post-operation rehabilitation treatment. Despite a lack of convincing evidence to date to prove its medical effectiveness, the results of reports are promising and we suggest further studies to be carried out using a more representative sample and a longer period of intervention, to more precisely evaluate the results of practising Pilates based exercises.

## 10. Acknowledgment

We would like to thank:

Anna Schabowska, an International Certified Coach of Pilates Method for providing the photos used in the chapter; Jagiellonian University Medical College in Krakow, Andrzej Frycz Modrzewski Krakow University, and the University School of Physical Education in Krakow for support to cover the cost of publication process.

## 11. References

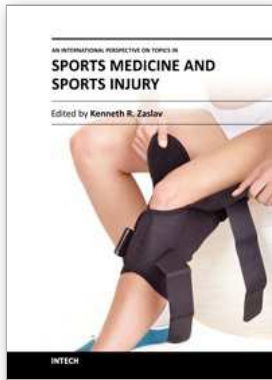
- Altan, L.; Korkmaz, N. ; Dizdar, M.&Yurtkuran, M. (2011). Effect of Pilates training on people with ankylosing spondylitis. *Rheumatol Int.* Apr 17. [Epub ahead of print]
- Arab, AM. & Nourbakhsh, MR. (2010). The relationship between hip abductor muscle strength and iliotibial band tightness in individuals with low back pain. *Chiropractic & Osteopathy*, 18, pp. 1-5
- Atkinson,DE.; Laver, JM. & Sharpvi, E. (2010). Physiotherapy and rehabilitation following soft-tissue surgery of the knee. *Mini-symposium: soft tissue surgery in the knee. Elsevier Ltd. Orthopaedics and Trauma.* Vol. 24, No.2, pp. 129-138
- Bliss, L. & Teeple, P. (2005). Core stability: the centerpiece of any training program. *Current Sports Med. Reports*, Vol 4, pp. 179-183
- Blum, CL. (May 2002). Chiropractic and pilates therapy for the treatment of adult scoliosis. *J Manipulative Physiol Ther.*Vol.m 25, No. 4, pp E3
- Critchley, DJ.; Pierson, Z.& Battersby, G. (2011). Effect of Pilates mat exercises and conventional exercise programmes on transversus abdominis and obliquus internus abdominis activity: pilot randomised trial. *Man Ther.*Vol.16, No. 2, pp. 183-9

- Culligan, PJ, ;Scherer, J. ; Dyer, K. ; Priestley, JL. ;Guignon-White, G. ;Delvecchio,D.& Vangeli, M. (2010). A randomized clinical trial comparing pelvic floor muscle training to a Pilates exercise program for improving pelvic muscle strength. *Int Urogynecol J Pelvic Floor Dysfunct.* Vol. 21, No 4,pp. 401-8
- Dyzkiewicz, A.; Wróbel, Z. & Rumanowski, M. (2003). The 3-D system of breathing track analysis in selected clinical cases. *Physiotherapy.* Vol. 11,pp. 13-20
- Emery, K.; De Serres, SJ.; McMillan, A & Côté, JN. (2010). The effects of a Pilates training program on arm-trunk posture and movement. *Clin Biomech.* 25, pp. 124-130
- Eyigor, S.; Karapolat, H.; Yesil, H.; Uslu, R.& Durmaz, B. (2010). Effects of Pilates exercises on functional capacity, flexibility, fatigue, depression and quality of life in female breast cancer patients: a randomized controlled study. *Eur J Phys Rehabil Med.* Vol. 46, No. 4, pp. 481-7
- Fiz, J. & Gnitecki, J. (2008). Effect of body position on lung sounds in healthy young man. *Chest,* 133:729- 736
- Gioftsidou, A.; Ispirlidis, I.; Pafis, G., Malliou, P., Bikos, C.& Godolias, G.(2008) Isokinetic strength training program for muscular imbalances in professional soccer players. 2, pp 101-105
- Gupta, V.; Singhal, R.& Ansari, M. (2005). Spontaneous rupture of the diaphragm. *Eur. Emerge. Med.* Vol. 12, pp. 43-44
- Helenius, I.; Tikkanen, H. & Haahtela, T. (1998). Occurrence of exercise induced bronchospasm in elite runners. Dependence on atopy and exposure to cold air and pollen. *Br. J. Sports Med.* Vol. 32, pp. 125 - 129
- Herrington, L. & Davies, R. (2005). The influence of Pilates training on the ability to contract the Transversus Abdominis muscle in asymptomatic individuals. *J Bodyw Mov Ther.* 9, pp. 52-57
- Horst, R. (2010). Trening strategii motorycznych i PNF. Motor strategy training and PNF. *Top School.* ISBN: 9788392984207
- Jago, R.; Jonker, ML.; Missaghian, M. & Baranowski, T. (2006). Effect of 4 weeks of Pilates on the body composition of young girls. *Prev Med.* Vol. 42, No.3, pp. 177-80
- Johnson, EG.; Larsen, A.; Ozawa, H.; Wilson, CH.& Kennedy, K. (2007). The effects of Pilates-based exercise on dynamic balance in healthy adults. *J Bodyw Mov Ther.* 11, pp. 238-242
- Kaesler, DS.; Mellifont, RB.; Swete Kelly, P.& Taaffe, P. (2007). A novel balance exercise program for postural stability in older adults: A pilot study. *J Bodyw Mov Ther.* 11,pp. 37-43
- Keays, KS.; Harris, SR.; Lucyshyn, JM.& MacIntyre, DL. (2008). Effects of Pilates Exercises on Shoulder Range of Motion, Pain, Mood, and Upper-Extremity Function in Women Living With Breast Cancer: A Pilot Study. *Phys Ther,* Vol. 88, No.4, pp. 494-510
- Lange, C.; Unnithan, V.; Larkam, E.& Latta, PM. (2000). Maximizing the benefits of Pilates-inspired exercise for learning functional motor skills. *J Bodyw Mov Ther,* Vol. 4, No. 2,pp 99-108

- Latey, P. (2001). The Pilates method: history and philosophy. *J Bodyw Mov Ther*, Vol. 5, No.4, pp. 275-282
- Latey, P. (2002). Updating the principles of the Pilates method – Part 2. *J Bodyw Mov Ther*, Vol. 6, No. 2, pp. 94-101
- Levine, B.; Kaplanek, B. & Jaffe, WL. (2009). Pilates Training for Use in Rehabilitation after Total Hip and Knee Arthroplasty. *Clin Orthop Relat Res*. Vol. 467, No. 6, pp. 1468-1475 Symposium: advanced techniques for rehabilitation after total hip and knee arthroplasty.
- Lim, EC.; Poh, RL.; Low, AY.&Wong, WP. (2011). Effects of Pilates-based exercises on pain and disability in individuals with persistent nonspecific low back pain: a systematic review with meta-analysis. *J Orthop Sports Phys Ther*. Vol. 41, No.2,pp. 70-80
- McNeill, W. (2011) Decision making in Pilates. *J Bodyw Mov Ther*. 15,pp. 103-107
- Mętel, S. & Milert A. (2007) Metoda Josepha Pilatesa oraz możliwości jej zastosowania w fizjoterapii (Joseph Pilates' method and its application in physiotherapy). *Reh Med* 11 (2): 27-36
- Muscolino, JE. & Cipriani, S. (2004). Pilates and the “powerhouse”. *J Bodyw Mov Ther*. 8, pp.15-24
- Page, P. (2005). Muscle Imbalances in Older Adults. *Journal of Active Aging* 4(2):30-39
- Pontaga.(2003). Muscle strength imbalance in the hip joint caused by fast movements Mechanics of Composite Materials, 39:4,365-368 *Latvian Academy of Sports Education*, Riga, LV-1006, Latvia. Translated from *Mekhanika Kompozitnykh Materialov*, Vol. 39, No. 4, pp. 549-554
- Rakowska, J. (1990). Breathing in the diagnosis tootsy resistance. *Psychotherapy*, 4; pp. 75-82
- Rogers, K. & Gibson, AL. (2009). *Eight-week traditional mat Pilates training-program effects on adult fitness characteristics*. *Res Q Exerc Sport*. 2009. Vo. 80, No.3:pp.569-74
- Siqueira Rodrigues, BG.; Ali Cader, S.; Bento Torres, NV.; Oliveira, EM. & Martin Dantas, EH. (2010). Pilates method in personal autonomy, static balance and quality of life of elderly females. *J Bodyw Mov Ther*. Vol.14, No.2 :pp. 195-202
- Szczygieł, E.; Rojek, M. & Golec, J. (2010). Forced postural distortions and the level of spirometric values. *Orthop. Quart.*, Vol. 3; pp. 439-451
- Szucs, K.; Navalgund, A.& Borstad, JD. (2009). Scapular muscle activation and co-activation following a fatigue task. *Med Biol Eng Comput*. 47:pp. 487-495
- Weiler, J.; Layton, T.& Hunt, M. (1998). Asthma in United States Olympic athletes who participated in the 1996 Summer Games. *J. Allergy Clin. Immunol*. Vol. 102, pp. 722 - 726
- Wroński, W.; Nowak, M. (2008). Pilates breathing exercise method as a form of pneumological rehabilitation in children and youths with bronchiale asthma. *Przegląd Lekarski*. Vol. 65, Suppl 2, pp. 9-11
- Volpi, P.; Melegati, G.; Tornese, D.& Bandi ,M. (2004). Muscle strains in soccer: a five-year survey of an Italian major league team. *Knee Surg Sports Traumatol Arthrosc*. 12 : pp. 482-485

Yang, Y.; Park, J. & Kim, J. (2010). Spontaneous diaphragmatic rupture complicated with perforation of the stomach during Pilates. *Am. J. Emerg. Medic.*, Vol. 28, pp. 259.e1-259.e3

Zocchi, L.; Fitting, W. & Majani, U. (1993). Effect of pressure and timing of contraction on human rib cage muscle fatigue. *Am Rev Respir Dis*, Vol 147, pp. 857- 864



## **An International Perspective on Topics in Sports Medicine and Sports Injury**

Edited by Dr. Kenneth R. Zaslav

ISBN 978-953-51-0005-8

Hard cover, 534 pages

**Publisher** InTech

**Published online** 17, February, 2012

**Published in print edition** February, 2012

For the past two decades, Sports Medicine has been a burgeoning science in the USA and Western Europe. Great strides have been made in understanding the basic physiology of exercise, energy consumption and the mechanisms of sports injury. Additionally, through advances in minimally invasive surgical treatment and physical rehabilitation, athletes have been returning to sports quicker and at higher levels after injury. This book contains new information from basic scientists on the physiology of exercise and sports performance, updates on medical diseases treated in athletes and excellent summaries of treatment options for common sports-related injuries to the skeletal system.

### **How to reference**

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Sylvia Mętel, Agata Milert and Elżbieta Szczygieł (2012). Pilates Based Exercise in Muscle Disbalances Prevention and Treatment of Sports Injuries, An International Perspective on Topics in Sports Medicine and Sports Injury, Dr. Kenneth R. Zaslav (Ed.), ISBN: 978-953-51-0005-8, InTech, Available from: <http://www.intechopen.com/books/an-international-perspective-on-topics-in-sports-medicine-and-sports-injury/pilates-based-exercise-in-muscle-disbalances-prevention-and-treatment-of-sports-injuries>

**INTECH**  
open science | open minds

### **InTech Europe**

University Campus STeP Ri  
Slavka Krautzeka 83/A  
51000 Rijeka, Croatia  
Phone: +385 (51) 770 447  
Fax: +385 (51) 686 166  
[www.intechopen.com](http://www.intechopen.com)

### **InTech China**

Unit 405, Office Block, Hotel Equatorial Shanghai  
No.65, Yan An Road (West), Shanghai, 200040, China  
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元  
Phone: +86-21-62489820  
Fax: +86-21-62489821

© 2012 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the [Creative Commons Attribution 3.0 License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.