Effects of Pilates training on neck-shoulder posture and movement

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CONTRIBUTIONS OF AUTHORS

Kim Emery, the candidate, developed this research project and participated in every step of this project. The candidate gave all the Pilates classes and wrote the research article.

Julie N. Côté, the candidate's supervisor was involved in all decisions about the elaboration of the research protocol, the data collection and the data analysis. She was also implicated in the revision of this research article.

Sophie J. DeSerres, Ph.D.,and Ann McMillan, M.Sc. were members of the candidate's committee and were implicated in the revision of this research article.

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ABSTRACT

The purpose of this Master's project was to investigate the effects of a 12-week Pilates training program on neck-shoulder posture and motion, core strength and neck-shoulder kinematics and muscles activity associated with a shoulder flexion task performed under six different conditions. After the training, scapula anterior tilt and upper and lower thoracic extension were reduced and there was increased activity of the rectus abdominis, serratus anterior and rhomboid muscles during the shoulder flexion task; passive shoulder range of motion increased in flexion and internal rotation; static thoracic kyphosis was smaller and abdominal strength was greater. Theses results suggest that Pilates is effective in improving core strength, thoracic static and dynamic posture, and shoulder flexibility as well as in stabilizing core posture as limb movements are performed. Our results support the use of the Pilates method in the rehabilitation, and possibly in the prevention, of neck-shoulder disorders.

RÉSUMÉ

Le but de ce projet de Maîtrise était d'étudier les effets d'un entraînement Pilates de 12 semaines sur la posture et le mouvement du complexe cou-épaule, ainsi que sur la cinématique et l'activité musculaire du complexe cou-épaule pendant la réalisation d'une tâche de flexion de l'épaule dans six différentes conditions. Nos résultats indiquent qu'après l'entraînement, la scapula avait une bascule antérieure diminuée; l'extension thoracique du tronc était diminuée; l'activité musculaire des abdominaux, grand dentelé et rhomboïde était augmentée; les amplitudes de mouvement passif de l'épaule en flexion et rotation interne était augmentées; la cyphose thoracique était diminuée et la force des abdominaux inférieurs était augmentée. Ces résultats suggèrent que le Pilates améliore la force des abdominaux, la posture thoracique, la flexibilité de l'épaule et la stabilité du tronc pendant le mouvement de segments. Nos résultats supportent l'utilisation du Pilates comme méthode de réadaptation, et possiblement prévention, des blessures cou-épaule.

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INTRODUCTION

The shoulder is a complex joint that includes synchronous movement of the scapula, the humerus and the clavicle (Ebaugh et al., 2005). Shoulder flexion is a functional motion that requires more strength than other functional movements due to the fact that this motion is typically done against gravity (Ludewing and Cook 2000). As the arm is raised towards the ceiling, the scapula performs an external rotation, upward rotation and a posterior tilt; the humerus performs an elevation followed by an external rotation and the clavicle performs an elevation followed by a retraction (Ebaugh et al., 2005). This coordinated motion involves muscles of the neck, shoulder and trunk and is essential for normal function of the shoulder girdle. Impairment to those muscles may alter the motion of the scapula, clavicle and/or humerus (Ebaugh et al., 2005).

Many studies have investigated shoulder biomechanics with and without dysfunction of the shoulder girdle (Lin et al., 2005; Klopar et al., 2006; Borstad et al., 2002; Wang et al., 1999; Borstad et al., 2005). Altered shoulder biomechanics has been found in patients with shoulder disorders and could be a cause or an effect of shoulder pain and restricted range of motion. In most patients with shoulder dysfunction (restricted range of motion, pain, impingement), the scapula produces less posterior tipping and upward rotation and increased scapula elevation as the arm is raised toward the ceiling. Moreover, shoulder flexion is often accomplished alongside an extension, rotation and lateral flexion of the thoracic spine. This suggests that the alignment of the spine may be closely related functionally to shoulder kinematics and it is also believed that a misalignment of the cervical and thoracic spine could be one of the factors that lead to occasional and/or chronic pain (Theodoridis and Ruston 2002).

Pilates is a physical training approach that focuses on posture, flexibility, segmental alignment, core control, proper breathing, precision and fluidity of movement (Latey, 2001-2002; Lange, 2000; and McMillan et al., 1998), through posture and movement exercises supported by verbal instructions from the Pilates instructor. At the beginning, emphasis is made on the control of the static posture (i.e. maintain a neutral spine with natural curves). With appropriate feedback from the instructor, patients learn to control the pelvic girdle using voluntary contractions of the deep abdominal muscles and to control the shoulder girdle using scapula stabilizers (latissimus dorsi and serratus anterior) (Muscolino and Cipriani 2004, McMillan et al., 1998). As the voluntary control improves, the emphasis is moved to segmental alignment during motion and spine mobility. With practice, it is believed that Pilates improves posture, control of the shoulder and pelvic girdle and segmental alignment and that those benefits could maintain and/or improve motion mechanics and reduce the risk of shoulder injuries (Anderson et al., 2000).

The effects of Pilates training are known in the ballet dancer's community because most of the studies have been done on ballet dancers in relation to this population's frequent occurrence of lower limb injuries (Henderson et al., 1993; McLain et al., 1997; McMillan et al., 1998). Nowadays, Pilates is practiced by people around the world and for a variety of reasons such as a rehabilitative approach or for injury prevention (Von Sperling de Souza et al., 2006). However, only few studies have rigorously and empirically tested the effect of Pilates on healthy adults and its effects on shoulder kinematics have never been experimentally and quantitatively shown (Bernardo, 2007).

The main objective of this Master's project is to test the effects of a Pilates training program on shoulder kinematics and muscular activity associated with a shoulder flexion task, performed with or without guidance, with or without resistance and with or without verbal feedback from the Pilates instructor. Subjects were tested before and after a 12-week, two sessions per week training regimen. The experimental protocol was conducted at the Jewish Rehabilitation Hospital in Laval and the Pilates training were given at the Montreal Pilates Center.

REVIEW OF THE LITERATURE

Relationship between posture and the incidence of neck-shoulder disorders

Across the lifespan, one's posture of the shoulder and the neck is affected by a variety of factors such as gravity, repetitive motion, computer work and many more (McLean 2005; Szeto et al., 2005). Because the shoulder is a complex joint and involves many muscles, impairments to bones and/or muscles may affect the neck-shoulder kinematics and muscles' coordinated activity (Ebaugh et al., 2005). Thus, many recent studies conducted on neck-shoulder biomechanics attempted to quantitatively describe posture and movement impairment in populations of neck-shoulder disorders (Wang et al., 1999; Borstad et al., 2002; Borstad et al., 2005; Lin et al., 2005). A better understanding of an injured and/or painful shoulder will help therapists focus on specific muscles that directly affect shoulder mechanics. Moreover, better studies on muscle impairment, altered biomechanics and posture of populations of neck-shoulder disorder patients may lead to more efficient prevention treatment.

Ludewig and Cook (2000) studied the effects of arm elevation with different loads on shoulder kinematics and associated muscles activity in people with symptoms of shoulder impingement. Their results showed that in subjects with shoulder impingement, there was less upward rotation at the end of the first phase (31°-60°), whereas posterior tipping was smaller in the last phase (91°-120°) and the internal rotation was higher in the 2 different load conditions across all phases of the motion. At the same time in the shoulder impingement group, the upper and lower trapezius muscle activity was higher in the final two phases (61°-120°) in the heavier load conditions and the serratus anterior muscle activity was lower. Authors suggested that the lower serratus activity in the patient group was related to the reduced posterior tipping and upward rotation of the scapula. This study highlights the fact that the mechanics of the scapula may be different in specific phases of the entire movement and in different loading conditions. In the impingement syndrome group, the serratus anterior as well as the upper trapezius muscle seem to be important muscles closely related to scapula biomechanics. People with shoulder impingement showed altered scapular kinematics which should be addressed in rehabilitation program. The altered scapula biomechanics in people with shoulder impingement has been also found in other studies. Lukasiewicz et al. (1999) and Borstad et al. (2002) both found that a shoulder impingement group showed an increase in anterior tipping of the scapula. Borstad et al. (2002) also found a decreased upward rotation between 40 and 60 degrees of arm elevation in the impingement group. Moreover, Lukasiewicz et al. (1999) found that the scapula demonstrated a greater elevation in the symptomatic group. Even if these two studies did not look at muscle activation, one could associate the more anterior tilt and elevated position of the scapula to a greater upper trapezius contraction as suggested by Ludewig and Cook (2000).

In the following years, Lin et al. (2005) studied the effects of four functional tasks on the kinematics of the scapula. The purpose of this study was to characterize the scapula kinematics and muscle activity in people with and without shoulder disorders (pain and/or restricted range of motion) while they performed either of one overhead task or three shoulder height (lifting-reaching-pushing) tasks. The results of this study showed that individuals with shoulder dysfunctions had less posterior tipping and upward rotation and higher scapula elevation. The muscle activity analysis of these tasks revealed less activation of the serratus anterior and more activation of the upper trapezius and anterior deltoid in patients with shoulder dysfunctions. According to the authors, the limited range of motion or pain at the shoulder joint affected the movements of the scapula (decreased posterior tipping and upward rotation) such that in order to compensate for this altered kinematics, patients may have had to elevate the scapula using the upper trapezius and anterior deltoid, the purpose of which is thought to be to clear space for the subacromial tissue. These findings suggest that shoulder rehabilitation approaches should include scapula posterior tipping, upward rotation, elevation and strengthening of the serratus anterior, upper trapezius and anterior deltoid. These results are in agreement with the previous studies on shoulder impingement and were also found in patients with shoulder instability. A study conducted by Matias et al. (2006) found that patients with shoulder instability showed less posterior tipping and greater protraction of the scapula. They also found that the lower trapezius and serratus anterior seemed to be more active after the end of the second third of the humeral elevation phase. According to the authors, the reduced muscle activation (lower trapezius and serratus anterior) at the beginning of the motion could represent inadequate muscular control which would be directly related to the shoulder instability. Moreover, Endo et al. (2004) found that there was a decrease in posterior tipping and upward rotation angle of the scapula with age. According to all previous research and to the authors, a loss of posterior tipping and upward rotation could be a predisposition to shoulder impingement syndromes and altered scapula kinematics could result from muscle weakness. Thus, there is belief that a prevention treatment that would address scapula biomechanics could potentially reduce the risk of developing shoulder impingement.

While all of the above mentioned studies contribute to say that shoulder dysfunction may be associated with decreased posterior tipping and upward rotation of the scapula, McClure et al. (2006) have obtained contrasting results. They measured scapular kinematics in 45 subjects with shoulder impingement and 45 asymptomatic subjects. Subjects were asked to lift their arm in the sagittal and scapular planes. The results showed that subjects with shoulder impingement had slightly greater upward rotation and posterior tipping and a deficit in isometric force production and range of motion. The authors concluded that the measurement methods and subjects differed from previous studies and that the difference in shoulder kinematics could be interpreted as favourable compensatory responses to increase subacromial space. Moreover, they suggested that scapular motion among patients with impingement syndrome simply may be highly variable, which was also suggested by Matias et al. (2006) who found differences in the shoulder kinematics among subjects with shoulder instability. Finally, in the McClure study, it is also possible that the task was not challenging enough to reveal altered scapula biomechanics or differences in muscle activation patterns such as those demonstrated by Ludewig and Cook (2000). Even if the literature shows variable results of scapula kinematics in patients with shoulder disorders, all studies concluded that more work is necessary to accurately assess scapular kinematic patterns so as to better estimate the importance of their impairment in shoulder patient populations.

Other studies have suggested that posture could also be an important factor in shoulder-neck pain (Hebert et al., 2002; Szeto et al., 2005). These authors have proposed that misalignment of the cervical and thoracic spine could lead to overuse injury of the shoulder and the neck. According to McLean (2005), 60% of individuals with neck pain display forward head posture (ear in front of the glenohumeral joint, in the sagittal plane), which may require more muscle activation (levator scapulae, upper trapezius, supra-spinatus, posterior deltoid, rhomboids, cervical erector spinae and sterno-cleido-mastoid) compared to that in the correct posture (ear aligned with the glenohumeral joint) in the sitting position. Forward head posture over long-duration tasks likely leads to muscle irritation, fatigue and chronic neck and shoulder pain (McLean, 2005). Moreover, some studies have suggested that posture of the thoracic spine may affect the kinematics of the scapula. Kebeatse et al. (1999) studied the effect of thoracic posture on scapula biomechanics. The study showed that in a slouched posture (forward head posture and increased thoracic kyphosis (convex curvature of the thoracic spine)), the scapula produced less posterior tipping and greater elevation. There was also less active shoulder range of motion in the slouched posture. Finley et al. (2003) obtained very similar results and also showed that the scapula moved to a more protracted position in the slouched posture. Smith et al. (2002) studied the effect of scapula protraction on isometric strength and found that there was a decrease in force production of the shoulder when the scapula was protracted. This can be explained by the fact that increased thoracic kyphosis and forward head posture bring the scapula in an anterior tilt and protracted position which restricts the range of motion of the shoulder and decreases the subacromial space, potentially leading to shoulder impingement. Moreover, this type of posture decreases the potential for force production at the shoulder and puts more stress on neck muscles which could lead to neck-shoulder disorders. Therefore, there is strong evidence to suggest that treatment that would attempt to correct neck-shoulder posture could potentially reduce risks of neck-shoulder disorders.

Neck-shoulder rehabilitation approaches

Some studies have suggested that abnormal posture and altered scapula and shoulder kinematics may result from muscle imbalance and weakness, which highlights the importance of rehabilitation and preventive programs (Kebaetse et al., 1999; Finley et al., 2003; Wang et al., 1999; Hagberg et al., 2000; Endo et al., 2004; Dayanidhi et al., 2005). Even if the role of the scapula has received considerable interest in the recent years, only few studies were conducted on the effects of physical exercise or rehabilitation on neck-shoulder pain (Sauers, 2005). Voight and Thomson (2000) have emphasized on the importance of the role of the scapula in the rehabilitation of shoulder injuries. They proposed that weakness of the scapulothoracic muscles leads to abnormal positioning of the scapula, altered length-tension relationships of the rotator cuff muscles and general shoulder dysfunctions. They suggest that the most commonly weak muscles of the neck-shoulder complex are the serratus anterior, rhomboids and lower trapezius. Another research conducted by Cools et al. (2007) studied the efficacy of 12 selected dumbbell and pulley exercises to restore muscle balance between the upper, middle and lower parts of the trapezius and the serratus anterior. Because many studies have suggested that muscle imbalance could be related to scapular dysfunction and shoulder pain, the goal of the research was to find exercises that minimize the activation of the upper trapezius and increase the activity of the middle and lower trapezius and serratus anterior. They found that it was possible to modify the intramuscular ratio (UT/LT, UT/MT) of the three trapezius parts using proper scapular exercises but none of the 12 exercises seemed to affect the intramuscular ratio of the serratus anterior and the upper trapezius (UT/SA). In light of their findings, authors suggested that it is possible to select exercises to strengthen the middle and lower trapezius while avoiding the activation of the upper trapezius, which could in turn help in the treatment of scapular muscle imbalance and shoulder pain. A research conduct by Wang et al. (1999) studied the effects of stretching and strengthening exercises on tridimensional shoulder kinematics of asymptomatic subjects. In this, subjects performed Theraband™ exercises (resisted scapular retraction, scapular elevation, shoulder abduction, shoulder external rotation and pectoral stretch) for 6 weeks, after which they displayed no difference in the static rest position of the scapula, however when the arm was elevated at 90 degrees, the scapula displayed less upward rotation, less elevation and more internal rotation. McClure et al. (2004) also studied the effect of a 6-week exercise program on shoulder function and tridimensional kinematics in people with shoulder impingement. The program included resistive strengthening, stretching and postural exercises that were done daily at home. They found an improvement in pain, satisfaction and function and increased isometric force. However, they found no significant difference in shoulder kinematics and thoracic posture. Three reviews on the effects of rehabilitation in shoulder-impingement patients (Sauers, 2005), of physiotherapy intervention for shoulder pain (Green et al., 2003) and of exercise therapy in mechanical neck disorders (Sarig-Bahat, 2003) concluded that physical therapy may be effective in decreasing pain and restoring normal function. However, most studies included in these reviews presented small sample sizes and variable methodological quality which limits the interpretation of their results. Nevertheless, the literature tends to show that it is possible to restore scapular muscle balance such that shoulder kinematics can be modified. The importance of strengthening lower scapular muscles (middle and lower trapezius and serratus anterior) is more often mentioned in the treatment of shoulder dysfunctions. However, contradictory results suggest that there is need for further research on the efficacy of such exercises in reducing neck-shoulder symptoms.

Effects of Pilates-based training

Until the 1980s, the Pilates Method was little known outside the dance community. However, it has gained and expanded in popularity in the last decades. With this increased popularity, several categories of Pilates based training approaches emerged in the middle 1990s. Today, one can divide all styles in two basics schools: the repertory approach and the modern Pilates (Latey, 2001). The repertory approach is closely related to Joseph H Pilates' method. It includes the original exercises and principles and induces minimal change for different body types. On the other hand, the modern Pilates method uses Joseph Pilates' philosophy with modified principles. The addition of Pre-Pilates exercises allows a more gradual integration and takes better account of new research and knowledge of the body. The exercises are similar but they are aimed at being adapted to a person's needs. Modern Pilates has been influenced by diverse fields such as physical therapy, somatic education and Chinese medicine. That is why, today, Modern Pilates is often called Pilates-based or Pilates–inspired training. Pilates exercises can be done on a mat or on specific apparatus called the Reformer and the Trapeze table. Nevertheless, all the different kinds of Pilates approaches focus on the control of the pelvic girdle with the deep abdominal muscles and the control of the shoulder girdle from the scapula stabilizers. As the control (voluntary and precise recruitment of the scapula and pelvic stabilizers) improves, the emphasis is moved to segmental alignment during motion, spine mobilisation and stability during sit-to-stand (Lange et al., 2000; Anderson et al., 2000). Another characteristic of Pilates-inspired exercise is the specific feedback of the instructor in assisting training. Based on the understanding of some basic motor learning principles of skill acquisition and performance, instructors give verbal and tactile cues to direct the learner's attention to task-relevant stimuli (Lange et al., 2000). Those cues are important for the learner to focus on internal and external body stimuli. They increase the feedback received by the learner about the success of the movement or the quality of the movement execution. For example, cues may be given on how to maintain the neutral spine and pelvis position, which muscles to use to maintain the desired position, and sometimes the instructions are used to favour a better body awareness approach (e.g. "what did you feel during the motion and which muscle did you feel?") The goals of the Pilates instructors are that the clients develop quality of new movement patterns and that they be able to transfer the acquired patterns to more functional tasks of daily living (Lange et al., 2000).

Pilates training has been studied by several researchers but none of the studies found addresses the impact of this training method on shoulder function. Pilates is a training approach that historically was first used in the dancing community; as a consequence, most of the original reported studies on Pilates training in the scientific literature focused on lower limb alignment and rehabilitation of dancers (McLain, 1997; Brown et al., 1996; Fitt et al., 1994; Henderson et al., 1993; Loosli et al., 1992). All theses studies concluded that Pilates training has significant effects on lower limb alignment which could lead to deceased risk of lower limb injury. In 1998, McMillan et al. conducted a study on the effects of Pilates-based training on dancers' dynamic posture. They trained 5 young ballet dancers for 23 private sessions (on a period of 14 consecutive weeks) and a daily home program. They used a WATSMART infrared light emitting diode system to capture marker displacement during a typical dance movement (Grand Pliés). The results indicated that the dancers were able to maintain a better pelvis–shoulder alignment and reduced upper body sway relative to the pelvis during the Grand pliés which suggests a better control of the motion. The authors concluded that Pilates training may be effective in improving the dynamic posture of dancers.

In the years following that study, Pilates gained in popularity and studies on Pilates principles and effects as a rehabilitation training approach were published (Latey, 2002-2001; Lange et al., 2000; Ives et al., 2000 and Anderson et al., 2000). Although these studies have effectively reported on Pilates as a training approach, they generally have not attempted to quantify its effects using validated biomechanical tools. A recent study has tested the efficacy of Pilates mat classes conducted once a week for two months on flexibility and body composition (Segal et al., 2004). They measured fingertip-to-floor distance, height, Body Mass Index (BMI) and general health using a questionnaire. The results showed significant increases in the fingertip-to-floor distance which suggests an improved flexibility of the posterior chain (calf, hamstrings and back muscles), with height and body composition staying the same. Another study, conducted by Jago et al. (2006) found that a 4 week, one hour per day, 5 days a week of Pilates training program reduced the BMI of a group of 11-years-old girls. The authors suggested that even if Pilates exercises are not considered aerobic exercises, they can still impact on the BMI. However, Jago et al. (2006) did not restrict the subjects to participate in other activities. Thus, further research is needed on more general populations and on longer and more intensive training programs. Because Pilates is practiced by more and more people, many studies were published in the last 3 years. Herington and Davies (2005) showed that Pilates training allowed a population of healthy subjects to better contract and maintain a transversus abdominis contraction than a group trained with regular abdominal curl exercises or a control group. In this study, 36 women (12 from Pilates classes, 12 from abdominal curl classes and 12 non active) were submitted to a transverse abdominal isolation exercise and a lumbo-pelvic stability test. Deep abdominal muscles are known to provide a specific contribution to spinal stability. Thus it is thought that well-trained transverse abdominis muscles could reduce the risk of lower back pain (Herington and Davies 2005), suggesting benefits of Pilates training in low back pain prevention. In 2007, a research conducted by Sekendiz et al. studied the effects of Pilates training (three times a week for five weeks of group mat classes) on abdominal and lower back muscular strength, abdominal muscular endurance, posterior trunk flexibility, body fat and BMI. The results indicated that Pilates training induced significant changes in abdominal and lower back strength, abdominal muscular endurance and in posterior trunk flexibility. No changes were observed for the body fat and BMI. The authors concluded that Pilates mat exercises increased quality of life of their subjects, which were sedentary adult women. Since the majority of the studies were conducted with Pilates group classes, Johnson et al. (2007) studied the effect of a Reformer Pilates training program on dynamic balance in healthy adults. Two groups of 20 subjects were tested for dynamic balance using the functional reach test (FRT). The experimental group completed 10 semi-private sessions (not more than 5 subjects per session) within 5 weeks. The results showed that the experimental group obtained significant improvement in balance after the Pilates training in opposition with the control which did not demonstrate significant change. The authors concluded that Pilates Reformer classes help to improve dynamic balance in healthy adults. Finally, a literature review, published in 2007 by Bernado, suggests that further research should more clearly describe subject recruitment procedures as well as the Pilates training programs administered. According to the author, the lack of scientific research on Pilates is disappointing for such a popular type of training method.

In conclusion, although some recent studies have investigated the effects of Pilates training on some aspects of posture and movement, none have investigated the effect of Pilates training on neck and shoulder biomechanics. There is an evident need for scientific research on the effect of Pilates. The literature agrees to say that posture, scapular kinematics and muscle weakness must be considered as risk factors for shoulder dysfunctions and that they must be considered in rehabilitation programs for neck-shoulder disorders. Because of Pilates' emphasis on posture and strengthening of the trunk and shoulder stabilizers, studying the effects of Pilates training on shoulder biomechanics may reveal some benefits of this training method, which could prove beneficial in the field of prevention and rehabilitation.

RESEARCH ARTICLE

The effects of a Pilates training program on neck-shoulder posture and biomechanics associated with a shoulder flexion task.

Kim Emery, Sophie J. DeSerres, Ph.D., Ann McMillan, M.Sc., Julie N. Côté

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Abstract

Objectives: to determine the effect of a 12 week Pilates training program on seated posture and flexibility, shoulder, scapula and trunk movement and muscular activity related to shoulder flexion.

Design: A repeated measures design was used. Measurements were taken before and after a 12-week Pilates-based exercise program.

Setting: Rehabilitation hospital; training centre.

Participants: 10 healthy volunteers (mean: 33.1 years, 5 men and 5 women) with no history of shoulder pain or limited range of motion in the past 6 months.

Interventions: Pilates training program consisting of 2 one-hour sessions per week for 12 weeks.

Main Outcome Measures: Trunk and scapula motion kinematics and activity amplitude of 16 neck-shoulder muscles during a shoulder flexion task, passive shoulder range of motion, static thoracic kyphosis and lower abdominal strength.

Results: After the training, scapula anterior tilt (p= 0.03) and upper and lower thoracic extension (p= 0.014 and p= 0.032) were reduced and there was increased activity of the rectus abdominis, serratus anterior and rhomboid muscles during the shoulder flexion task; passive shoulder range of motion increased in flexion and internal rotation; static thoracic kyphosis was smaller (t =0.01) and abdominal strength was greater (t =0.013).

Conclusion: Pilates is effective in improving core strength and upper spine posture as well as in stabilizing core posture as limb movements are performed. Since deficits in these functional aspects have previously been associated with symptoms in the neck-shoulder region, our results support the use of the Pilates method in the rehabilitation, and possibly in the prevention, of neck-shoulder disorders.

Key Words: neck-shoulder kinematics, Pilates training, electromyography, posture.

Introduction

Across the lifespan, one's posture of the shoulder and the neck is affected by a variety of factors such as gravity, repetitive motion, computer work and many more (McLean 2005, Szeto et al., 2005). The shoulder is a complex joint that includes synchronous movement of the scapula, the humerus and the clavicle (Ebaugh et al., 2005). Shoulder flexion is a functional motion that requires considerable strength due to the fact that this motion is typically accomplished against gravity (Ludewig and Cook 2000). As the arm is raise towards the ceiling, the scapula performs an external and upward rotation and a posterior tilt; the humerus performs an elevation followed by an external rotation and the clavicle performs an elevation followed by a retraction (Ebaugh et al., 2005). This motion involves coordinated actions of muscles of the neck, shoulder and trunk that are essential for normal function of the shoulder girdle. Impairment to those muscles may alter the motion of the scapula, clavicle and/or humerus (Ebaugh et al., 2005).

Many studies have investigated shoulder biomechanics with and without dysfunction of the shoulder girdle (Lin et al., 2005; Klopar et al., 2006; Borstad et al., 2002; Wang et al., 1999; Borstad et al., 2005). Recent work has found that people with shoulder dysfunctions shows less posterior tipping, more anterior tipping, less upward rotation and more elevation of the scapula. Moreover, some of those studies found that there was a decreased activity of the serratus anterior and an increased activity of the upper trapezius in people with shoulder impingement or dysfunctions (Ludewig and Cook, 2000; Lukasiewicz et al., 1999; Borstad et al., 2002; Lin et al., 2005). It has been suggested that this altered shoulder biomechanics could be a cause or an effect of shoulder pain and restricted range of motion. According to previous research, a loss of posterior tipping and upward rotation could be a predisposition to shoulder impingement syndrome, and altered scapula kinematics could result from muscle weakness. Thus, there is belief that a prevention treatment that would address scapula biomechanics could potentially reduce the risk of developing shoulder impingement.

Other studies have suggested that posture could also be an important factor in shoulder-neck pain (Hebert et al., 2002; Szeto et al., 2005). These authors have proposed that misalignment of the cervical and thoracic spine could lead to overuse injury of the shoulder and the neck. Moreover, some studies have suggested that posture of the thoracic spine may affect the kinematics of the scapula. Theses authors explained that an increased thoracic kyphosis and a forward head posture may bring the scapula in an anterior tilt and protracted position which restricts the range of motion of the shoulder and decreases the subacromial space, potentially leading to shoulder impingement (Kebeatse et al., 1999 and Finley et al., 2003). Finally, some studies have suggested that abnormal posture and altered scapula and shoulder kinematics may result from muscle imbalance and weakness, which highlights the importance of rehabilitation and preventive programs in order to avoid these pathological conditions and/or reduce their impact (Kebaetse et al., 1999; Finley et al., 2003; Wang et al., 1999; Hagberg et al., 2000; Endo et al., 2004; Dayanidhi et al., 2005).

Until the 1980s, the Pilates Method was little known outside the dance community. However, it has gained and expanded in popularity in the last decades (Latey, 2001). Pilates exercises can be done on a mat or on specific systems called the Reformer and the Trapeze table. As a general rule, the Pilates approach focuses on the control of the pelvic girdle with the deep abdominal muscles and the control of the shoulder girdle from the scapula stabilizers. As the control (voluntary and precise recruitment of the scapula and pelvic stabilizers) improves, the emphasis is moved to segmental alignment during motion, spine mobilisation and stability during sit-to-stand (Lange et al., 2000; Anderson et al., 2000). Another characteristic of Pilates-inspired exercises is the specific feedback of the instructor in assisting training. Based on the understanding of some basic motor learning principles of skill acquisition and performance, instructors give verbal and tactile cues to direct the learner's attention to task-relevant stimuli (Lange et al. 2000). Those cues are then used by the learner to focus on internal and external body stimuli. Moreover, they increase the feedback received by the learner about the success of the movement or the quality of the movement execution.

The effects of Pilates training on the biomechanical characteristics of the body have been studied by several researchers but none of the studies found addresses the impact of this training method on shoulder function. Since Pilates was first used in the dancing community, most of the early studies on Pilates training in the scientific literature focused on lower limb alignment and rehabilitation of dancers (McLain, 1997; Brown et al., 1996; Fitt et al., 1994; Henderson et al., 1993; Loosli et al., 1992). As a whole, they found that Pilates improves dynamic posture in ballet dancers as well as in healthy adults (McMillan et al., 1998; Johnson et al., 2007). Moreover, recent studies outside of the dance community found that Pilates training induced significant changes in deep abdominal and lower back strength, abdominal muscular endurance and in posterior trunk flexibility (Herington and Davies 2005; Sekendiz et al., 2007). Despite this recently increased interest in Pilates research, no studies have investigated the effect of Pilates training on neck and shoulder biomechanics. Thus, there is an evident need for scientific research on the effect of Pilates on neck-shoulder function.

The literature agrees to say that posture, scapular kinematics and muscle weakness must be considered as risk factors for shoulder dysfunctions and that these factors should be accounted for in rehabilitation programs for neck-shoulder disorders. Because of Pilates' emphasis on posture and strengthening of the trunk and shoulder stabilizers, studying the effects of Pilates training on shoulder biomechanics will validate the use of this training method, which could in turn prove beneficial in the field of prevention and rehabilitation. Thus, the main goal of this research is to test the effects of a Pilates training program on trunk and shoulder posture and biomechanics associated with a shoulder flexion task performed under different conditions. We hypothesized that the Pilates program would be effective in improving posture as well as improving scapula and shoulder motion characteristics associated with healthy shoulder function.

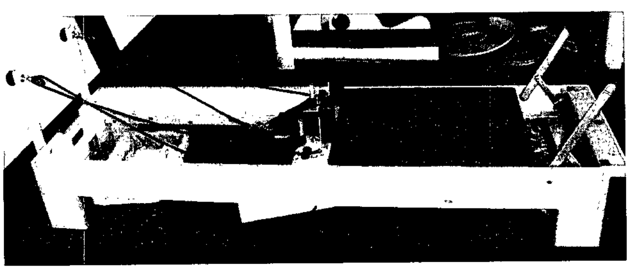
Method

Subjects and study design

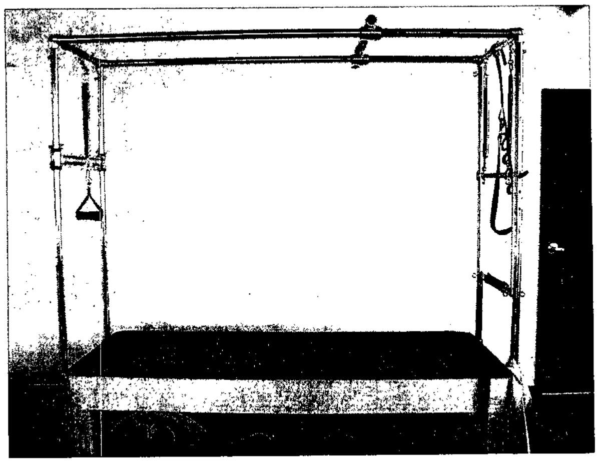
A group of 10 healthy subjects aged 25-46 years (mean age= 33.1; 5 women, 5 men) participated in this study. Subjects were recruited from personal contacts and public advertisements. Subjects were excluded if they experienced pain or limited ranged of motion of the shoulder and/or neck in the previous 6 months and if they had any experience of Pilates classes. Each subject signed a consent form approved by the institutional ethics committee. The group performed the experimental protocol a first time, and then they were trained according to the Pilates method twice a week in private sessions for 12 weeks. After the 12 weeks of training, the subjects performed the experimental protocol again. The biomechanical assessment took place at the Research Center of the Jewish Rehabilitation Hospital in Laval and the Pilates training took place at the Centre Pilates de Montréal.

Pilates training

The training of the experimental group was given by the same instructor and a daily home program was added during the 12 weeks. The training consisted of 2 one-hour sessions per week for 12 weeks of exercises on a mat, the Universal Reformer and the trapeze table. The Reformer and the trapeze table are body-conditioning systems that use springs to assist or resist motion (figure 1). The springs provide tension ranging between 1 kg and 15 kg (McMillan et al., 1998).



a)



b)

Figure 1.a) exercise on the Reformer, **b)** exercise on the trapeze table.

At the beginning, a typical session included supine exercises that require movements of the segments while involving the abdominal muscles to maintain the spine and the pelvis in a neutral position, with a goal of training clients to dissociate movements of the trunk and limbs, and of neighboring joints as a whole. Supine arm exercises with and without resistances were progressively added to gradually strengthen the scapula stabilizers and develop control of the shoulder girdle movements. Spine motions such as flexion and extension were slowly introduced. Small equipment like balls and foam rollers were gradually added to challenge postural stability due to their ability to decrease the stability of support surfaces. At mid-treatment, a typical session included supine, sitting and quadruped exercises. The difficulty of these exercises was gradually increased and the focus was maintained on keeping a neutral aligned posture in different gravity orientations so as to add challenges to the trunk and scapula stabilizers. Spine movements (flexion, extension, lateral flexion and rotation) were added to those that targeted strengthening of abdominal and back muscles. Finally, kneeling and standing exercises were performed. Verbal and tactile cues were given by the instructor throughout the training sessions. At the beginning, verbal and tactile cues addressed general ideas of the correct actions (position of the shoulder and the pelvis) and as the subject gained more control, cues focused on more specific aspects of alignment of the limbs and the spine and precise muscle recruitment (Lange et al., 2000). As a whole, the difficulty of the exercises was increased towards the end and typically, every major part of the body was trained in each session. Finally, various positions and equipment were progressively added to better represent the day-to-day activities in order to facilitate transfer and autonomy beyond the Pilates session (Anderson et al., 2000)(Table 1).

Table 1 description of typical sessions at different stage of the training

Beginners	Intermediate	Advanced
Trapeze table: - pistons - arms arcs - scapula mobilisation with the Tower Bar Reformer: - legs extensions - arms arcs - bridges - legs arcs and circles with feet in the cords - arms series seated on the box - scooter	Trapeze table: - scapula mobilisation with the Tower Bar, lying on a half foam roller - roll-down - scapula mobilisation with the Tower Bar seated on ball Reformer: - unilateral legs extension - arms circles - quadruped exercise - legs series feet in the cords (frog and skiing) - thoracic extension on the box - mermaid (lateral spine flexion) - seated arms series on the box	Trapeze table: - scapula mobilisation with the Tower Bar, lying on foam roller - teaser - roll-down on foam roller - scapula mobilisation with the Tower Bar seated on ball, feet on balance board - lat pull down Reformer: - legs series with feet in the cords - resisted arms series and thoracic extension lying on stomach - abdominal series seated on carriage facing head - legs series standing on the Reformer

Experimental protocol

Static posture

Subjects were seated on a bench with no back rest and were asked to keep a natural static posture. This allowed us to measure angles between the neck, shoulder, thoracic and lumbar spine to reflect the static postural alignment.

Dynamic posture

In order to measure shoulder flexion forces and to apply resistance in the resisted shoulder flexion trials, we used the Simulator II (Bte-technologies, Baltimore, USA). The Simulator II consists of an exercise head attached to an arm that slides vertically on a large pole. In order to test shoulder flexion, we used an attachment tool consisting of a rigid metal bar with a square plate at one extremity on which subjects pushed upward with their forearm, which was pronated. The forearm was strapped against the pole to insure arm stability without restricting the motion of the shoulder. Subjects were seated on a bench beside the exercise head. The axis of rotation of the attachment tool was aligned with the glenohumeral joint of the subjects. All subjects performed the tasks with their dominant arm.

Figure 2 experimental set up

Subjects were then asked to perform different tasks. The first task was to perform a maximal isometric voluntary of shoulder flexion effort (MVE) starting from two different positions. The attachment tool was locked to have the shoulder at 90 degrees and the subjects were asked to push as hard as possible against the pad towards the ceiling. Then, subjects were asked to repeat the task with the shoulder at 150 degrees. Following this, subjects were asked to perform 24 trials of shoulder flexion in 6 different conditions (4 trials of each condition indicated below).

Table 2 experimental conditions

With the bar	Resistance	Pilates instruction (BRI)
		No Pilates instruction (BR)
	No Resistance	Pilates instruction (BI)
		No Pilates instruction (B)
Without the bar of the simulator II	Pilates instruction (I)	
	No Pilates instruction (N)	

The order of the 6 conditions was randomly selected for each subject and the same order was used for the pre and post-training tests. For all trials, the general instructions were to flex the arm at a comfortable speed, as high as possible, and gradually return to the starting position. In trials with resistance, the resistance value was set at 50% MVE (identified during the 150 degrees shoulder flexion task). In the trials without the bar, subjects were asked to perform the shoulder flexion task but didn't benefit from guidance to restrict their motion in the sagittal plane. In the Pilates instruction trials, prior to each trial, subjects were instructed to move the arm as high as possible without moving the shoulder blade and as they moved, they were instructed to "sit straight up and as you exhale, move your arm up, slide your shoulder blade down and hold your stomach in". After the completion of the shoulder flexion protocol, passive range of motion (pROM) of the shoulder (flexion, external rotation and internal rotation) and lower abdominal strength were measured using a goniometer (Kendall, 2001), with the recorded angle for the later test corresponding to the angle between legs and the floor. In this, the subjects were instructed to lie on their back and to start with both legs straight up toward the ceiling with the lower back totally pushed in the mat. Then, they were asked to lower their legs toward the floor keeping their back pushed in the mat. When they were unable to maintain the lower back in the mat, they were asked to stop and the measurement was taken.

In the post-test, subjects repeated the same protocol and two other conditions were added at the end of the 24 shoulder flexion trials. Because the resistance was set at 50% MVE, and we hypothesized that there would be changes in shoulder flexion MVE following Pilates training we added two resistance shoulder flexion conditions with the resistance set at the same absolute resistance value recorded during the pre-Pilates session (corresponding to BRI pre and BR pre). Finally, at the end of the post-training protocol, subjects were asked to complete a questionnaire on expected and perceived effects of the training.

Data acquisition

Kinematics of the head, arms and trunk was recorded using a high resolution six-camera Vicon 512 Motion Analysis System (Vicon Peak, UK). Reflective markers were placed over the following anatomical landmarks: left and right sides of the forehead, left and right posterior sides of the head, C7 spinous process, left and right T1 transverse processes, scapula posterior acromion, spine root of the scapula, scapula inferior angle, T6 spinous process, left and right T8 transverse processes, T12 spinous process, left and right L1 transverse processes, S1, left and right postero-superior iliac spine, left and right antero-superior iliac spine, sacrum, sternum, left and right acromio-clavicular joint, right lateral epicondyle, and right head of third metacarpal. Kinematic data was sampled at 120 Hz. To allow computation of arm and trunk kinematics, the following anthropometric measures were taken: trunk depth at T1, T4, T10, and L3 levels; body height and body weight (see figure 3)

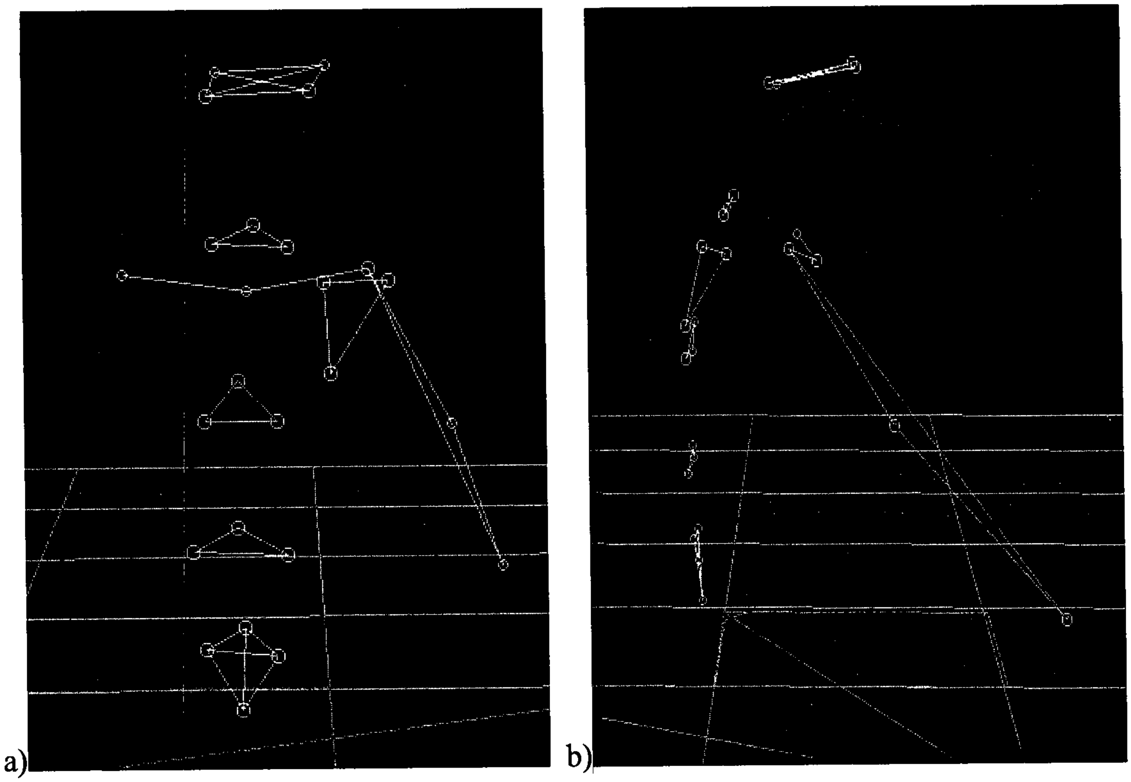


Figure 3. a) marker set frontal plane, b) market set sagittal plane

The activity of 16 muscles of the neck, arm and trunk was measured using the Telemyo 900 electromyographic system (Noraxon, USA). In order to obtain good signals, the skin was cleaned, shaved and slightly abraded. Adhesive bands were used to fix the electrodes on the skin to minimize electrode movement. Bipolar surface Ag/AgCl electrodes (Ambu, DE) were then placed over the following neck, shoulder and trunk muscles, on the dominant side unless noted otherwise: cervical erector spinae (CES, bilateral), sterno-cleido-mastoid (SCM), anterior deltoid (AD), upper trapezius (UT), serratus anterior (SA), rhomboid (ROM, bilateral), latissimus dorsi (LAT), lower trapezius (LT), lumbar erector spinae (LES, bilateral), external oblique (EO, bilateral), rectus abdominis (RA, bilateral) (Basmajian, 1983). Ground electrodes were placed over the right elbow epicondyle and the left anterior acromion. Electromyographic data was sampled at 1080 Hz.

Data analysis

Kinematic data was low-pass filtered (zero-lag second order Butterworth filter, 6 Hz). The three markers of the scapula (posterior acromion, spine root, inferior angle) were used to define the scapula segment and to calculate scapula's rotations relative to the global space. The scapula upward rotation was defined as the counterclockwise rotation of the scapula in the frontal plane, posterior tipping was defined as the counterclockwise rotation of the scapula in the sagittal plane and anterior tipping was defined as the clockwise rotation in the sagittal plane, with respect to a task performed with the right arm (Wu et al., 2005). An average position of the three scapula markers was also calculated in time to measure scapula global linear displacement. Shoulder flexion angle was determined by the angle of the humerus segment relative to the trunk (T1-S1) segment (Wu et al. 2005). The trunk segment was further divided in three triangle sub-segments: the upper thorax (UpTX, T1-T6); the lower thorax (LwTX, T8-L1) and the lumbar segment (LUMB, L1-S1). The thoracic kyphosis was defined in the sagittal plane using the angle between the upper thoracic segment and the vertical (see figure 4)

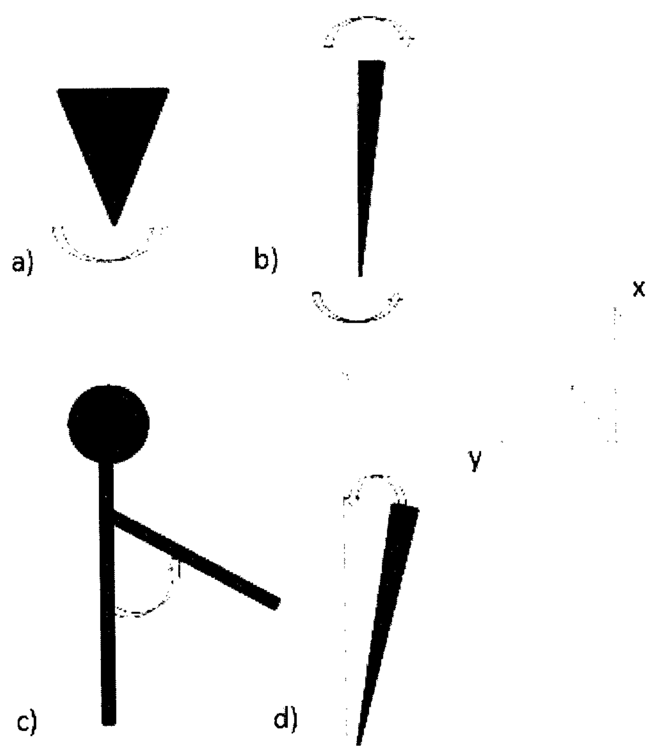


Figure 4. a) scapula and trunk segment rotation in frontal plane, b) scapula and trunk segment rotation in sagittal plane, c) shoulder flexion angle, d) thoracic kyphosis angle.

Heartbeats were removed from EMGs in each trial by first selecting a reference heartbeat in one signal and then applying a cross correlation to remove the corresponding parts of the signal in other muscles. The data were then filtered with a zero-lag second order band pass (20-500 Hz) filter. Signals were full-waved rectified. Root mean squares (RMS) of each EMG signal recorded during MVE trials were calculated over 100 ms windows. The maximum values for each muscle were then selected as the normalization signals. For each dynamic trial, the right shoulder angle was used as a reference to select 100-ms windows at four different flexion angles (90°, 120° corresponding to the upward flexion phase, -120° and -90° corresponding to the downward return phase). RMS values of each muscle were calculated over 100 ms windows at each angle. All the RMS values were finally normalized to the peak RMS of the MVE trials, to obtain normalized RMS (nRMS) values, expressed as % MVE RMS. All analyses were computed using Matlab v. 6.5.1 (The MathWorks, Inc., Natick, MA, USA).

Statistical analysis

The data were first averaged over trials for each subject. Each kinematic and EMG dependent variable was analyzed using a general linear model to assess the effects of the 6 conditions (BRI, BR, BI, B, I, N) and the training (pre vs. post). When main effects and/or interactions were significant, post-hoc Tukey tests were performed.

The effects of Pilates training on passive shoulder ROM, thoracic kyphosis during static posture and the lower abdominal strength test were analyzed using paired T-Tests. All statistical analyses were performed using Statistica, v.7 (Statsoft, Tulsa. OK, USA) and statistical significance was set at $p < 0.05$.

Results

Kinematics

Paired t-test analyses revealed that there was no significant effect of Pilates training on shoulder flexion MVE ($t = 0.07$). Therefore, the comparisons of conditions with resistance are only reported below for the trials where the resistance was 50%MVE determined during the given session. Moreover, there was a significant condition effect for all the kinematic variables (except for shoulder maximal abduction and upper thoracic range of motion in the medio-lateral direction). Therefore, the section below summarizes only the training, and training x condition interaction effects for each arm or trunk parameter studied. Moreover, unless noted otherwise, all results reported in the kinematics section below concern the upward phase of the shoulder flexion task.

Shoulder and trunk segment angles

Statistical analyses revealed that there was a significant training effect on several arm-trunk kinematic parameters (see Table 3; note that the means and standard deviations reported in Table 3 were averaged across all six conditions), with scapular motion being the most affected by Pilates training. Regardless of the conditions, scapula anterior tipping range of motion (measured during the downward phase) was significantly lower after training. Posterior tipping range of motion of the scapula was also significantly reduced after training. However, the significant training x condition interaction for posterior tipping analysis showed that only the three conditions with Pilates instructions showed a significant decrease with training (Figure 5). There was also a significant decrease in scapula posterior displacement after training, with a significant training x condition interaction showing that the posterior displacement was smaller in two of the three Pilates instructions conditions (instructions with bar, instructions with bar and resistance). The same interaction was found in the scapula medial/lateral displacement although there was no significant training effect on this variable. Finally, scapula upward rotation range of motion was not significantly affected by training, although a significant interaction revealed that upward rotation range of motion was significantly smaller in the no bar + instruction condition after training.

Table 3. Means (SD) and P-values of all kinematic parameters recorded during the shoulder flexion task.

KINEMATICS PARAMETERS	Pre-Pilates (mean (SD))	Post-Pilates (mean (SD))	P-values Training effect	P-values Interaction effect
Scapular segment ROM:				
Upward rotation	39.06 (8.02)	36.74 (8.81)	p= 0.513	p= 0.006*
Posterior tipping	17.29 (4.73)	13.05 (6.23)	p= 0.027*	p= 0.018*
Anterior tipping	14.44 (3.22)	11.70 (5.01)	p= 0.033*	p= 0.11
Scapular displacement ROM:				
Posterior	43.73 (20.28)	34.23 (19.72)	p= 0.035*	p= 0.03*
Medio/lateral	51.19 (23.72)	41.70 (22.86)	p=0.07	p= 0.003*
Upper Thoracic segment ROM:				
Lateral flexion	5.22 (1.82)	5.77 (2.26)	p= 0.227	p=0.314
Extension	11.67 (5.78)	8.28 (4.65)	p= 0.014*	p= 0.0003*
Low Thoracic segment ROM:				
Lateral flexion	4.26 (1.87)	4.09 (1.66)	p= 0.737	p= 0.948
Extension	5.45 (3.27)	3.30 (1.92)	p=0.032*	p= 0.268
Shoulder maximal angles:				
Flexion	145.35 (17.49)	146.64 (19.27)	p= 0.716	p= 0.001*
Abduction	13.97 (7.80)	16.42 (5.51)	p= 0.152	p= 0.627

NOTE: The means and standard deviations reported here were averaged across all six conditions

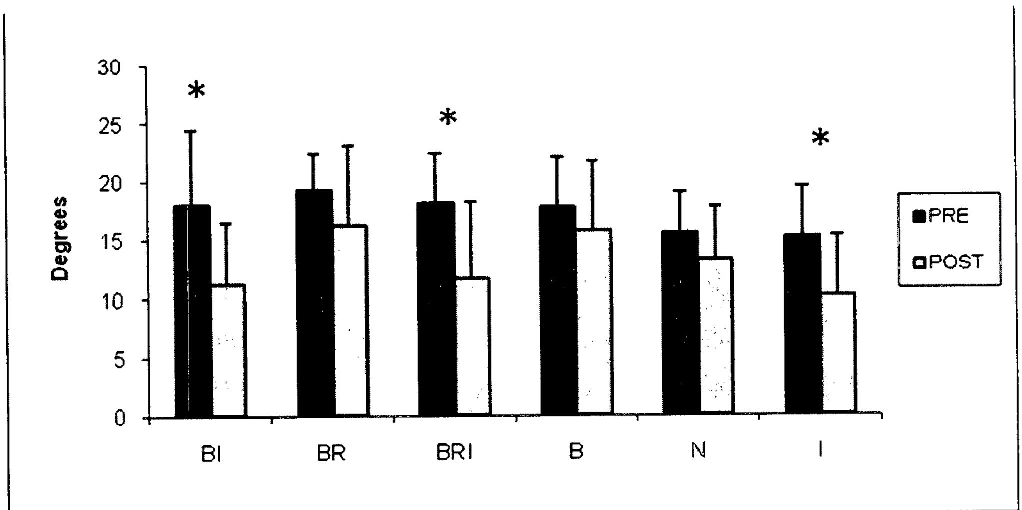


Figure 5: Scapula posterior tipping range of motion recorded during the shoulder flexion task performed at six different conditions (see Methods for description of tasks), with significant interaction effects (*)

There was a significant decrease of UpTX segment (T6 - T1) extension range of motion during the shoulder flexion task in the post-training. Moreover, a significant interaction revealed that UpTX segment extension was significantly smaller only for the three Pilates instruction conditions after training (Figure 6). Conversely, the UpTX segment range of motion in the medio-lateral direction did not show any significant difference after the training, nor was there a significant training x condition interaction. Analysis of the LwTX segment (T12 - T8) range of motion showed that there was a significant decrease of LwTX extension following training, with no training x condition interaction. However, LwTX range of motion in the medio-lateral direction did not show any significant training or interaction effects. Analysis of the LUMB segment (S1 - L1) did not reveal any significant training or interaction effects.

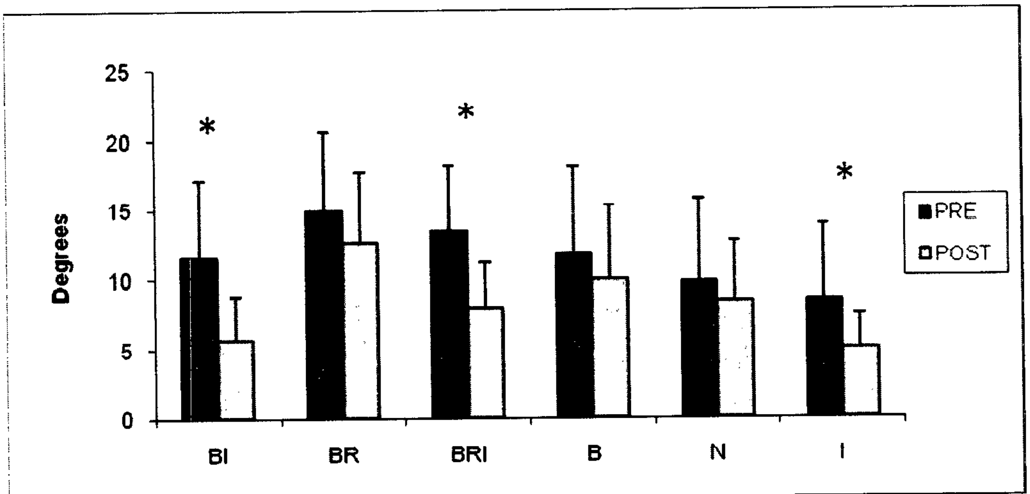


Figure 6: Upper thoracic segment range of motion recorded during the shoulder flexion task performed at six different conditions (see Methods for description of tasks), with significant interaction effects (*)

Finally, statistical analysis of shoulder maximal flexion and abduction during the shoulder flexion task did not show any significant effects of training. However, there was a significant training x condition interaction effect for maximal flexion angle, but not for maximal abduction.

Shoulder passive range of motion (pROM), lower abdominal strength and static posture
The analysis of the shoulder passive range of motion indicated a significant increase of shoulder internal rotation and shoulder flexion after Pilates training (Table 4). However, there was no significant training effect on external rotation (t =0.553). The lower abdominal strength test also showed a significant increase in the post-training. Finally, static thoracic kyphosis was significantly reduced after training.

Table 4. Means (SD) and t-values of shoulder pROM, lower abdominal strength test and thoracic kyphosis in pre and post-test

	PRE	POST	T-TEST
Shoulder pROM :			
Internal Rotation	38°(11.6°)	47.5°(6.8°)	t =0.003*
External rotation	90.2° (6.5°)	91.4° (6.8°)	t =0.553
Flexion	164.2° (8.9°)	168.4°(7.7°)	t =0.03*
Abdominal Strength	43°(11.3°)	27.8°(9.6°)	t =0.00004*
Thoracic Kyphosis	20.4°(6.2°)	15.4°(4.1°)	t =0.01*

EMG

Upward phase (shoulder flexion) (Table 5)

At 90°, there was a significant training effect on three of the sixteen muscles. The activation was higher in the post-training in the RCES and LROM muscles, and lower in the RLES muscle. There was a significant interaction effect for seven muscles. In particular, this analysis revealed significant increases in RCES, LROM and LRA EMG in conditions with Pilates instructions after training (with no other significant effects in condition without instructions) (Figure 7). There was a significant increase of activation in the post-training in some conditions for the LCES and LLES muscles. There was a significant decrease of activation in the post-training in the resistance condition for the LT muscle.

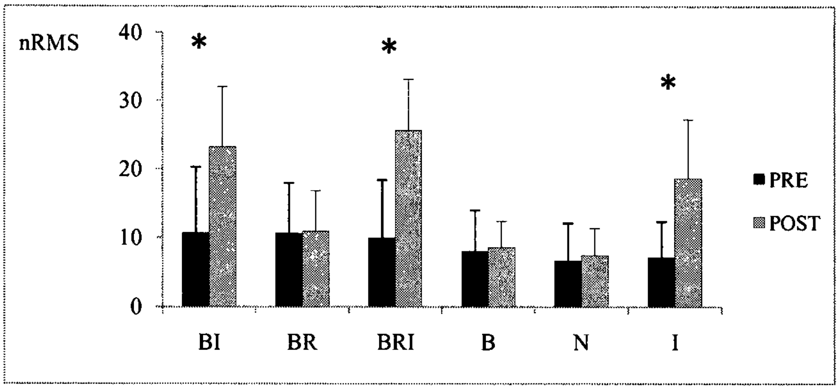
Table 5. Average (SD) EMG RMS change between pre and post-training and p-values of training and interaction effects in the upward shoulder flexion phase

Muscles		90°		
		% change	P-values Training effect	P-values Interaction effect
SCM				
CES		+165% (244%)	p=0.017	p<0.001
	L	+45% (93%)		p<0.001
UT				
AD				
SA				
LAT				
LT		+8% (99%)		p=0.02
ROM				
	L	+100% (110%)	p<0.001	p<0.001
EO	R			
	L			
RA				
	L	+76% (145%)		p<0.001
LES		-47% (28%)	p=0.001	p=0.027
	L	+95% (204%)		p<0.001

Muscles		120°		
		% change	P-values Training effect	P-values Interaction effect
SCM		+17% (68%)		p=0.006
CES	R	+131% (195%)		p=0.001
	L	+41% (65%)		p=0.001
UT		+12% (26%)	p=0.049	p=0.031
AD				
SA		+15% (28%)	p=0.035	p=0.006
LAT		+15% (48%)		p=0.008
LT		+9% (88%)		p<0.001
ROM	R			
	L	+114% (129%)	p=0.029	p<0.001
EO	R			
	L	+9% (106%)		p=0.002
RA	R			
	L	+60% (94%)		p<0.001
LES	R			
	L	+96% (181%)		p<0.001

NOTE: empty spaces represent non-significant results

At 120°, there was a significant training effect on three muscles, with the activation of the UT, SA and LROM muscles being significantly higher after Pilates training. There were also significant interaction effects for ten muscles. The muscles significantly affected by Pilates training in condition with Pilates instructions only were the LROM, LRA and LLES, which all showed increased EMG (Figure 7). Moreover, the LLES muscle showed a significant decrease of activation in the resistance condition in the post-training. There was a significant increase of activation in the post-test in some conditions for the SCM, LAT, RCES and LCES. There was a significant decrease of activation in the post-test in some conditions for the LEO and in the three conditions without Pilates instructions in the LT (See table 5 for more details).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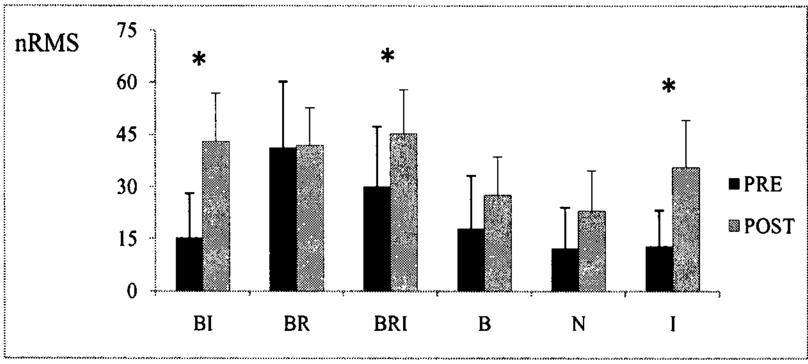
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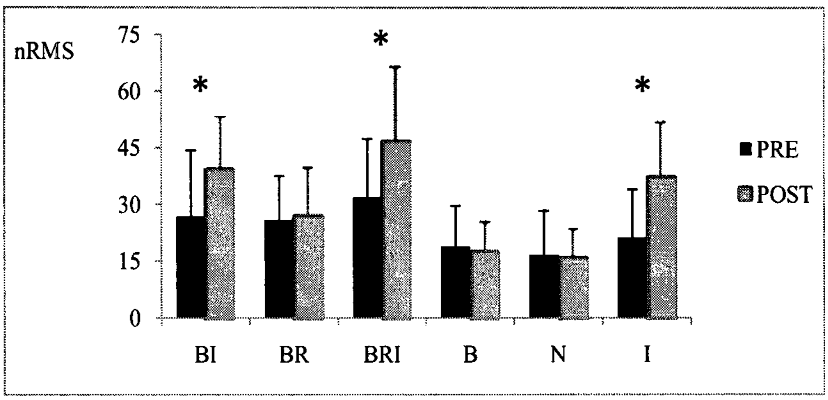
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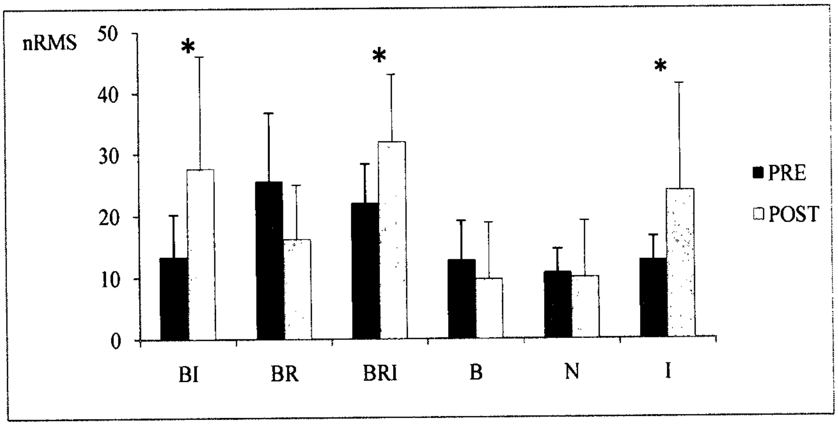

d)
Figure 7: nRMS of different muscles with significant interaction (*) for the three conditions with Pilates instructions (BI, BRI, I) a) RCES at 90° b) LROM at 120° c) LRA at 120° d) LLES at 120°. Note that LROM and LRA show similar results at 90°.

Downward phase (shoulder extension) (Table 6)

At -120°, there was a significant training effect on two muscles, with significantly higher LROM and lower RLES activation. There were significant training x condition interactions in three muscles. A significant increase of activation in the post-training was found in some conditions for the RRA muscle. A significant decrease of activation in the post-test was found in the conditions with the bar for the RLES muscle.

Table 6. Average (SD) EMG RMS change between pre and post-training and p-values of training and interaction effects in the downward phase of shoulder flexion (extension)

Muscles		-120 % change	-120 P-values Training effect	-120 P-values Interaction effect	Muscles		-90 % change	-90 P-values Training effect	-90 P-values Interaction effect
SCM					SCM				
CES	R				CES	R			
	L					L	+25% (87%)		p= 0.0009
UT					UT				
AD					AD				
SA					SA				
LAT					LAT				
LT					LT				
Rom	R				Rom	R	-30% (36%)	p=0.044	p=0.023
	L	+97% (109%)	p=0.033	p=0.0003		L	+72% (79%)	p=0.007	p=0.00001
EO	R				EO	R			
	L					L	-11% (74%)		p=0.003
RA	R	+21% (40%)		p=0.004	RA	R			
	L					L			
LES	R	-27% (45%)	p=0.026	p=0.004	LES	R	-35% (33%)	p=0.002	
	L					L			

NOTE: empty spaces represent non-significant results

Finally, at -90°, there were significant training effects on three muscles. The activation was higher in the post-training for the LROM muscle, and lower for the RROM and RLES muscles. There was a significant training x condition interaction effect for four muscles. A significant increase of activation in the post-training was found in the three Pilates instruction conditions of the LROM muscle (Figure 8) and in one condition of the LCES. A significant decrease of activation in the post-training was found in some conditions of the LEO muscle (see table 6 for more details).

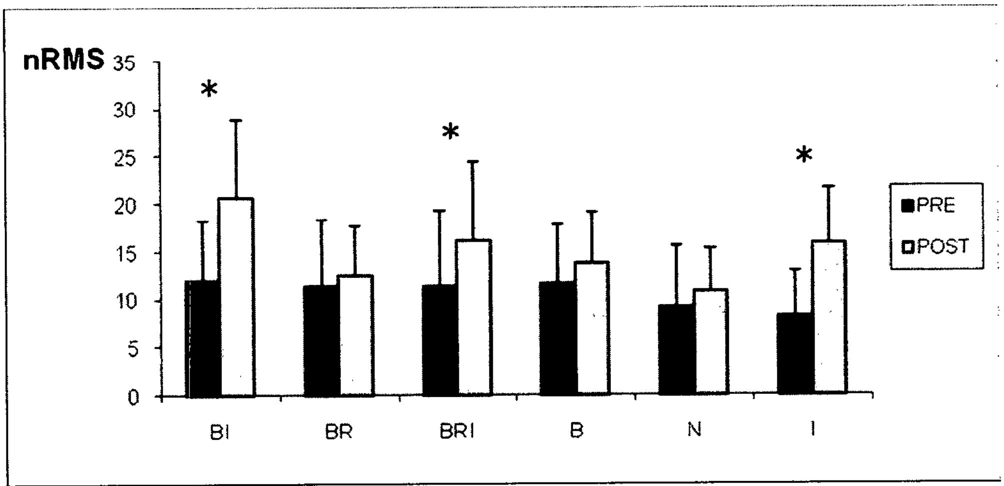

Figure 8: nRMS of LROM muscle with significant interaction (*) of the three conditions with Pilates instructions (BI, BRI, I) at -90°.

Questionnaires

The score of general appreciation of the Pilates training was 4.4 (1.07) on a scale of five. Subjects generally felt that they improved their posture (7/10), increased global muscular strength (6/10) and body awareness (6/10) and improved their well-being (6/10). Some subjects felt that they improved flexibility (4/10) and ability to relax (4/10). These comments are in subjective agreement with the objective measurements reported above such as posture, flexibility and a better control of the scapula and the spine, which can all be encompassed in the general concept of "body awareness".

Discussion

The purpose of this study was to investigate the effects of a 12-week Pilates training program on neck-shoulder posture and motion, core strength, and muscle activity associated with a shoulder flexion task performed under six different conditions. Previous work has shown that Pilates has a positive effect on posture, trunk stability, leg flexibility and deep abdominal strength (McMillan et al., 1998; Segal et al., 2004; Herington and Davies 2005). However, the effects of Pilates on neck-shoulder biomechanics had never been studied before. We chose to study a shoulder flexion task because it is a functional task, often produced against gravity and which involves many muscles of the shoulder girdle. Moreover, shoulder flexion is often affected by neck-shoulder dysfunction (Ludewig and Cook 2000; Lin et al., 2005; Ebaugh et al., 2005). The kinematic variables were analysed for the upward flexion phase (except for scapula anterior tilt) because there was nothing to suggest that the kinematic characteristics of the downward (shoulder extension) phase would be affected differently than that of the upward phase (Borstad and Ludewig 2002). Moreover, the upward flexion phase should better represent the effect of Pilates training because it is the harder of the movements. However, we believed that the downward phase could present some differences in terms of (eccentric) muscle activation strategies after the training. Thus, in this paper, we presented muscle activity data for both phases of movement.

Table 7. Summary of significant outcome measures according to the effect of the 3 conditions with Pilates instructions

Training effect (effect of Pilates)	Interaction effect (effect of the 3 instruction's conditions)	Training effect + interaction effect (effect of Pilates + effect of the 3 instruction's conditions)
Scapula anterior tipping ROM	LRA at 90° and 120°	Scapula posterior tipping ROM
Low Thoracic extension ROM	LLES t 120°	Posterior scapular displacement ROM
LLES at -90°		Upper Thoracic extension ROM
RLES at -90°		RCES at 90°
SA at 120°		LROM at 90°, 120° and -90°
RUT at 120°		

Shoulder and trunk biomechanics during the shoulder flexion task

Despite the fact that the Pilates program focused on shoulder range of motion, our results show that there was no significant difference in active shoulder maximal flexion and abduction angle recorded during the shoulder flexion task before and after the training. However, there was a significant training by condition interaction effect for maximal shoulder flexion angle. This suggests that the subjects were able to better dissociate the different task conditions (resistance, instructions, bar) after the completion of the Pilates program without limiting the total range of motion of their shoulder flexion. Moreover, other results show that although shoulder flexion outcome was not affected by Pilates, it was performed with significantly less motion of the shoulder girdle and the upper back, suggesting an increased ability to dissociate limb and core motion after Pilates training.

Scapula upward rotation did not show any significant difference before and after the training, which supports the findings of McClure et al. (2004). However, the major change in scapula kinematics is reflected in the posterior and anterior tipping ranges of motion. Both of them were reduced after the training, which illustrates a better stabilization of the scapula during the arm flexion task. Moreover, posterior tipping was found to be decreased after the training in the conditions with Pilates instructions. This suggests that with proper instructions, subjects were able to perform the task with the same shoulder flexion amplitude before and after the training, with a better control of the scapula in the post-training session. Moreover, anterior tipping of the scapula was reduced after the training, not only in the conditions with Pilates instructions but across the ensemble of conditions. In addition, muscle activation revealed that there was an increased activity of the serratus anterior when the shoulder reached 120° after the training, and this increase was even more apparent in the two conditions with resistance. Because it is believed that increased anterior tipping and decreased serratus anterior activity may contribute to shoulder dysfunction and impingement (Lukasiewicz et al., 1999; Borstad et al., 2002; Ludewig and Cook, 2000; Lin et al., 2005), the fact that Pilates training reduced anterior tipping and increased serratus anterior activity, without significant effect of the instructions, is relevant and suggests that Pilates could be considered as a rehabilitation or even a preventive approach.

Surprisingly, the upper trapezius muscle showed an increased activity at 120° after the training in the condition with resistance. This result could be explained by the fact that in the resistance condition, subjects were not instructed to stabilize the scapula and since this condition was the most challenging one of the group with no instructions, subjects could have chosen to use the upper trapezius more in this resistance condition, compared to all other conditions. Also, because the scapula showed less tipping range of motion after training, we would have expected to see an increased activity of the lower trapezius muscle. However, this muscle showed less activity in the three conditions without Pilates instructions at 120°, after training. It is possible that in the pre-training session, the lower trapezius was activated in the same way in all conditions and that in the post-training session, it was activated but much more so when the subjects were instructed to stabilize the scapula. Another explanation could be that other muscles (e.g. rhomboids, as shown in our results) contributed more importantly to restrict scapula tipping after the Pilates program.

The upper thoracic segment extension range of motion during the shoulder task was significantly smaller after the training, with post-hoc analysis displaying smaller motions only in the conditions with Pilates instructions. Moreover, the low thoracic segment extension range of motion showed a significant decrease in the post-training session through all conditions. As a whole, we could say that the thoracic spine was moving less in the post-training session without restricting the motion at the shoulder. The upper thoracic segment was stabilized only when subjects were asked to stabilize the scapula and to activate their abdominal muscles in opposition with the lower thoracic segment which was no affected by the instructions but by the training itself which indicates that the training had a greater effect on lower thoracic segment and that subjects were able to keep a more neutral posture after the training while performing the task and again, without restricting movement at the shoulder. Muscles activity of the left rectus abdominis revealed an increase at 90° and 120° only in the conditions with Pilates instructions and the left external oblique showed a decreased activity only in the without Pilates instructions condition at 120° and -90°. These findings suggest that the change in the left abdominal muscle after the training could reflect improved thoracic spine stabilization strategies. Pilates training focuses on increasing the control of the trunk and scapula from the abdominal muscles and scapula stabilizers. The efficacy of Pilates in improving these aspects seems to be supported by our results.

Posture

The static thoracic kyphosis was significantly smaller after training, which is in agreement with Wang et al. (1999) who found a decreased thoracic kyphosis after 6 weeks of stretching and strengthening shoulder exercises. It has often been suggested that thoracic posture influences scapula kinematics (Kebeatse et al., 1999; Finley et al., 2003; Smith et al., 2002). In our protocol, the decreased thoracic kyphosis could have helped to bring the scapula to a reduced anterior-tilted position. Because the thoracic posture was changed after the training, one could expect changes in the cervical and lumbar erector spinae muscle activation. In our study, the right cervical erector spinae showed an increased activity after the training in the conditions with Pilates instructions at 90° and 120°. The left cervical erector spinae was also increased in the no bar + instruction condition at 90° and in the instruction conditions at 120° and -90°. Szeto et al. (2005) suggested that an increased activity of the cervical erector spinae would represent a more efficient strategy to maintain the cervical spine in a neutral posture, as opposed to an increased upper trapezius activity as was shown in a group of symptomatic subjects. Moreover, it has been suggested that cervical muscle activation patterns would be altered in people with neck disorders and that corrected posture would translate into an increase in cervical muscle activity which could help restore normal cervical function (Falla et al., 2007). These strategies are also reflected in our findings. The increased activity of the left and right cervical erector spinae in our study occurs only in conditions with Pilates instructions which could be a result of the instructions to sit straight up (to correct their posture) and could represent a good strategy to maintain this posture.

There was no significant difference in the lumbar segment range of motion before and after the training. However, the right lumbar erector spinae was less activated in all conditions at 90° and in all conditions with the bar at -120°. Moreover, the left lumbar erector spinae showed an increased activity in conditions with Pilates instructions at 90° and 120° and a decreased activity in the resistance condition also at 120°. The increased activity of the left rectus abdominis seems to be related to the decreased activity of the right lumbar erector spinae. Moreover, there was increased activity of the left cervical erector spinae, left rhomboids and left lumbar erector spinae. As a whole, muscles of the left (non moving) side of the trunk seem to be closely related to the decreased range of motion of the upper and lower thoracic segment and to the decreased thoracic kyphosis after the training. Taken together, these results could indicate a more symmetrical spine stabilization pattern as the moving arm is raised and lowered during the shoulder flexion task, suggesting that the Pilates program has an effect on postural symmetry during limb movements.

Shoulder strength, passive range of motion and lower abdominal strength

After the Pilates program, subjects displayed increased passive flexibility of the shoulder in internal rotation and flexion but there was no difference in external rotation. It has been often suggested that Pilates increases flexibility however this had previously only been measured in the legs (Segal 2004, Sekendiz 2007). Because previous studies have shown significant effects of Pilates training on abdominal and back muscle strength (Herrington and Davies 2005, Sekendiz 2007), we expected to see an increase in muscle strength after the training which, in our case, would be illustrated by increased abdominal strength and shoulder flexion MVE. However, in our study, the results suggest that the lower abdominal strength was increased after the training but there was no significant difference in shoulder MVE before and after the training. This can be explained by the fact that the Pilates method focuses at the beginning on core strength and then on limb control, rather than on developing limb muscle strength from the beginning. Although the later phases of a typical Pilates training program do involve some muscle strengthening exercises, since the training was performed for 12 weeks, we feel that this may not have been long enough to allow significant gains in shoulder strength to take place. The ability of the Pilates method to significantly improve shoulder strength should thus be better assessed after a longer training period. The fact that abdominal strength, and not shoulder strength, was increased with Pilates supports the belief that this is a method that focuses on core strength, control and posture (Muscolino et al., 2004; Latey, 2002).

Pilates and functional activity

According to our results, some parameters such as scapula anterior tipping ROM, low thoracic segment extension ROM, thoracic kyphosis and serratus anterior muscle activity were affected by the training even in the no Pilates instructions experimental conditions which suggests that they are affected by the training itself rather than the instructions. In turn, this suggests that Pilates training will have a significant impact on the behaviour of these parameters in everyday life i.e. where instructions are not available to guide performance. The fact that some parameters such as scapula posterior tipping ROM, upper thoracic segment extension ROM and LROM muscle activity were affected by the training and more so inby the Pilates instructions conditions suggests that without proper instructions, such as in a real life situation, individuals would be less able to show a learning effect from the Pilates program. Thus, in the absence of verbal cues, the transfer of learning to functional activities may be limited. It is well-known that augmented verbal cues direct the learner's attention to critical elements of a motor skill and may lead to improved performance (Landin, 1994; Lange et al., 2000). However, it may happen that the learner becomes dependant of the verbal cues and their performance will decrease when augmented feedback is removed (Magill, 1994). Since in this project, Pilates training was limited to 12 weeks, it remains to be seen if, on a long-term basis, subjects would eventually be able to perform the motion the same way with as without instructions (McMillan et al., 1998, Segal et al.,2004). Nevertheless, some modification to the instruction characteristics could help to improve subjects' performance and reduce the potential to become dependant of the instructions. According to Magill (1994), the information provided by the feedback should be more precise and also address characteristics of the skill that need to be eventually changed or modified to continue improving performance beyond Pilates training. Moreover, training subjects to self-talk regimens would represent a better choice to improve performance and independence because this way the learner becomes more involved with the process of learning transfer (Landin, 1994).

Conclusion

The results of our study show that a 12-week Pilates training program was effective in improving core strength and posture as well as certain aspects of scapula and upper trunk stability during a shoulder flexion task. It should be kept in mind that this study was conducted on a rather small convenience sample of subjects (N = 10). Despite this, our results are consistent with the underlying hypotheses of the Pilates method, i.e. this method is effective in improving core strength and upper spine posture as well as in stabilizing core posture as limb movements are performed. Since deficits in neck-shoulder biomechanics have previously been associated with symptoms in the neck-shoulder region, our results support the use of the Pilates method in the rehabilitation, and possibly in the prevention, of neck-shoulder disorders.

Acknowledgments

We thank Karen Lomond and Jason Fuller for creating and sharing scripts for the data analysis. We also thank Ann McMillan, founder of the Montreal Pilates Center who graciously allowed us to use the Center's training facilities. This study was supported by funds from the Canadian Foundation for Innovation and the Jewish Rehabilitation Hospital Foundation.

CONCLUSION

This research highlights the effects of a Pilates training program on neck-shoulder and postural characteristics that are related to neck-shoulder disorders. We found that Pilates has an effect on scapula kinematics. Moreover, we found that the thoracic static posture was improved and that upper and lower thoracic movements were reduced during the accomplishment of the shoulder flexion task. The serratus anterior, the cervical erector spinae, non-dominant rhomboids, abdominals and lumbar erector spinae muscles were all more active during the shoulder flexion task after Pilates training. These results support the hypothesis that Pilates improves posture, allows better trunk stability while performing segment movement and increases scapula stabilization from stabilizers muscles. This study also confirms the importance of Pilates instructions. After the training, subjects showed better trunk and scapula stabilization when given appropriate verbal instructions, suggesting more body awareness and self control after a Pilates training program. Since some aspects of neck-shoulder movements that were affected by Pilates have also been found to be affected in people with neck-shoulder disorders, our results suggest that Pilates could be used as a rehabilitation approach and could potentially be used as a preventive training regimen for neck-shoulder disorders.

Our results open the way for research on the potential effects of Pilates on neck-shoulder rehabilitation approaches. Further studies should test the effects of Pilates on people with neck-shoulder disorders. Combined with clinical approaches to restore soft tissue function, Pilates could be a rehabilitation and training approach that progressively restores neck-shoulder function while providing patients with a better awareness of body position in space and improved ability to control their posture and arm movements. Also, since varieties of occupational activities such as prolonged driving, computer work and repetitive work performed at or above shoulder level have been shown to be linked with neck-shoulder disorders, we believe that Pilates could be integrated into work retraining, or even work injury prevention strategies. Although more research needs to be conducted on establishing the proper training modalities to restore such functions, we believe that our study supports more work in this direction.

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APPENDIX A

Ethics certificate

Comité d'éthique de la recherche
des établissements du CRIR

CRIR

Certificat d'éthique

Par la présente, le comité d'éthique de la recherche des établissements du CRIR (CÉR) atteste qu'il a évalué, lors de sa réunion du 20 juin 2006, le projet de recherche **CRIR-217-0506** intitulé:

« Effets de l'entraînement Pilates sur la posture et le mouvement du cou et de l'épaule».

Présenté par: **Julie Côté**

Le présent projet répond aux exigences éthiques de notre CÉR. Le Comité autorise donc sa mise en œuvre sur la foi des documents suivants :

- Formulaire A daté du 30 mai 2006 ;
- Document intitulé «Award Agreement» *Canada Foundation for Innovation*;
- Document intitulé « Budget du projet » ;
- Lettre et formulaire d'évaluation de la convenance institutionnelle de l'Hôpital juif de réadaptation, datés du 23 mai 2006, confirmant l'acceptation du projet sur le plan de la convenance institutionnelle ;
- Protocole de recherche intitulé « Effets de l'entraînement Pilates sur la posture et le mouvement du cou et de l'épaule» ;
- Formulaire de consentement, version française et anglaise (version du 20 juillet 2006, telle que datée et approuvée par le CÉR) ;
- Affiches de recrutement, version française et anglaise (version du 20 juillet 2006, telle que datée et approuvée par le CÉR).

Ce projet se déroulera dans le site du CRIR suivant : **Hôpital juif de réadaptation.**

Ce certificat est valable pour un an. En acceptant le présent certificat d'éthique, le chercheur s'engage à :

1. Informer le CÉR de tout changement qui pourrait être apporté à la présente recherche ou aux documents qui en découlent (Formulaire M) ;
2. Fournir annuellement au CÉR un rapport d'étape l'informant de l'avancement des travaux de recherche (formulaire R) ;
3. Demander le renouvellement annuel de son certificat d'éthique ;
4. Aviser le CÉR de la clôture (abandon ou interruption prématurée) du projet de recherche ;
5. Tenir et conserver, selon la procédure prévue dans la *Politique portant sur la conservation d'une liste des sujets de recherche*, incluse dans le cadre réglementaire

APPENDIX B

Consent Form

CRIR Centre de recherche interdisciplinaire en réadaptation du Montréal métropolitain

Consent form

Hôpital juif de réadaptation
Jewish Rehabilitation Hospital

1 - Title of project

Effects of Pilates training on neck-shoulder posture and movement

2 - Researcher in charge of project

Julie Côté, Ph.D. Assistant professor, Department of Kinesiology and Physical Education, McGill University, (514) 398-4184 ext. 0539, (450) 688-9550, ext. 4813

Kim Emery, M.Sc. kinesiology student, Department of Kinesiology and Physical Education, McGill University, (514) 688-4081

3 - Project description and objectives

The objective of this research is to study the effect of Pilates training on posture of the shoulder and the neck and shoulder movement. Participants with no previous Pilates experience will be recruited in either a control group or an experimental group. Both groups will twice perform an experimental protocol consisting of sitting posture recordings, and assessment of shoulder flexion movements, with and without resistance and with or without instructions. Between both experimental sessions, the experimental group will follow a 2-time per week, 15-week Pilates training program. The long-term objective of this research is to objectify the effectiveness of the Pilates method in improving neck-shoulder posture and movement.

4 - Nature and duration of participation

The research project to which I am invited to participate aims at understanding the mechanics of the shoulder and the spine, the coordination between muscles of the shoulder, neck and trunk and the effect of Pilates training on neck-shoulder posture and movements. The experimental procedure will be performed at the research center of the Jewish rehabilitation hospital. I am asked to participate in two sessions (pre and post-test) which will last approximately two hours each.

If I choose to participate in this study, I will be randomly assigned to either the experimental group or to the control group. If I am assigned to be part of the experimental group, both experimental sessions will be conducted before and after I participate in a 15-week Pilates training program conducted at the Montreal Pilates center. As part of this program, I will work on my posture, flexibility and muscle strength. I will attend two private Pilates session per week of 1 hour each. If I am assigned to the control group, both experimental sessions will be administered before and after a 15 week period during which I will be offered one Pilates group session as well as general information on Pilates. Also, I will have to fill out a weekly journal summarizing the physical activities accomplished during the previous week.

During each of the two experimental sessions, the preparation will last approximately one hour. Surface electrodes will be fixed on the skin over muscles of my neck, trunk and my dominant arm. Reflective markers will be fixed on the skin over my neck, trunk, dominant arm, hips and legs in order to record their positions. None of these procedures is invasive.

After the preparation phase, I will have to perform tasks of posture and of static and dynamic shoulder efforts. First, I will sit on a bench I will be asked to keep a natural static posture for 3 trials of 10 seconds each. This procedure will last approximately 15 minutes in total.

Then I will be asked to perform 3 trials of maximal shoulder flexion with my dominant arm. My upper arm will be placed parallel to the floor and I will have to push as hard as I can against a static metal bar. Then, I will have to perform a shoulder flexion task also from a sitting position. My forearm will be strapped against the metal bar. From this position, I will perform 20 trials in which I will have to lift my arm toward the ceiling, as high as I can, pushing against the bar. In half the trials I will have to flex my shoulder against added resistance provided by the metal bar, corresponding to half my maximal shoulder flexion strength. In the other half of the trials I will perform shoulder flexion with no added resistance. Also, in half the trials, I will be given verbal cues suggesting how I can use my muscles to perform the movement. In the other half of the trials I will not be given verbal cues. This procedure will last approximately 45 minutes in total.

5 - Advantages associated with my participation

As a member of the control group, I will not personally benefit from any advantages by participating in this study. However, I will contribute to the fundamental science of motor control, biomechanics and the applied science of occupational health. As a member of the experimental group, I will likely benefit from advantages linked to my participation in a Pilates training program, which may contribute to improving my overall health and well-being.

6 - Risks associated with my participation

None of the techniques used are invasive. I understand that my participation in this project does not put me at any medical risk.

7 - Personal inconvenient

The duration of each experimental session (approximately 2 hours each) may represent an inconvenience for me. The possibility that a few small areas (12, 3x3 cm each) of the skin over my neck, back and dominant arm may have to be shaved before positioning the electrodes might also be an inconvenience to me. Although it is hypo-allergenic, the adhesive tape used to fix the electrodes on my skin may occasionally produce some slight skin irritation. Should this happen, a hypo-allergic lotion will be applied on my skin to relieve skin irritation. Also, I may experience some slight fatigue towards the end of each protocol, which may cause some neck and shoulder muscle tenderness or stiffness. These symptoms should dissipate within 48 hours following the completion of the protocol. A clinician will be present at all times during the protocol in case of complications.

Also, Pilates training requires muscular efforts which may also induce fatigue or muscle stiffness in the 48 hours following each session. Notably, I may feel fatigue or soreness following my initiation to Pilates. It should be noted that these inconveniences underlie the initiation of any new physical activity. Each Pilates session will be conducted as a private session under professional supervision, and all the exercises will be adjusted to my expertise level. It is understood that I will be allowed to interrupt both the experimental and Pilates training sessions anytime I wish. Finally, the duration of the training program (15 weeks) may also represent an inconvenience.

8 - Access to my medical file

No access to my medical file is required for this study.

9 - Confidentiality

All the personal information collected for this study will be codified to insure confidentiality. Information will be kept under locking key at the research center of the Jewish Rehabilitation Hospital by one of the persons responsible for the study for a period of five years. Only the people involved in the project will have access to this information. If the results of this research project are presented or published, nothing will allow my identification. After this five-year period, data will be destroyed.

10 - Questions concerning the study

The researchers present during the testing should answer my questions concerning the project in a satisfactory manner.

11 - Withdrawal of subject from study

Participation in the research project described above is completely voluntary. I have the right to withdraw from the study at any moment. If ever I withdraw from the study; all documents concerning myself will be destroyed.

12 - Responsibility

By accepting to enter this study, I do not surrender to my rights and do not free the researchers, sponsor or the institutions involved from their legal and professional obligations.

13 - Monetary compensation

No monetary compensation will be given to me for participation in this protocol. If I am a subject of the experimental group, I will be offered free of charge a supervised Pilates training program for my participation in the research protocol. Even though I am at any time free to withdraw from participating in this study, I understand that my commitment to it should be serious, considering the investment and resources that the researchers dedicate to this research. If I am a subject of the control group, I will be offered information on Pilates as well as a group training session.

14 - Contact persons

If I need to ask questions about the project, signal an adverse effect and/or an incident, I can contact at any time Julie Côté, Ph.D., assistant professor, Department of Kinesiology and Physical Education, McGill University, (450) 688-9550, ext. 4813. For further questions related to this study, I may also contact Ms. Michelle Nadon, local commissioner for the quality of services at the JRH, at (450) 688-9550, extension 232.

Also, if I have any questions concerning my rights regarding my participation to this research project, I can contact Mme. Anik Nolet, Research ethics co-ordinator of CRIR at (514) 527-4527 ext. 2643 or by email at anolet.crir@ssss.gouv.qc.ca

CONSENT

I declare to have read and understood the project, the nature and the extent of the project, as well as the risks and inconveniences I am exposed to as described in the present document. I had the opportunity to ask all my questions concerning the different aspects of the study and to receive explanations to my satisfaction.

I, undersigned, voluntarily accept to participate in this study. I can withdraw at any time without any prejudice. I certify that I have received enough time to take my decision.

A signed copy of this information and consent form will be given to me.

NAME OF PARTICIPANT (print): ______________________________

SIGNATURE OF PARTICIPANT: ______________________________

SIGNED IN ____________________, **on** ________________, **20**_____.

COMMITMENT OF RESEARCHER

I, undersigned, ________________________________ , certify

(a) having explained to the signatory the terms of the present form ;

(b) having answered all questions he/she asked concerning the study ;

(c) having clearly told him/her that he/she is at any moment free to withdraw from the research project described above; and

(d) that I will give him/her a signed and dated copy of the present document.

____

Signature of person in charge of the project or representative

SIGNED IN __________________, on __________________________ 20__.