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Kinematic and Electromyographic Analysis of Lower Extremity Muscles during Rehabilitation Exercises: A Review

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Abstract
Occupational workers need to perform activities like pulling, pushing, lifting etc. during their work-day. These activities require high strength of muscles of lower extremities (LE), which include quadriceps, hamstrings and gastrocnemius. Rehabilitation exercises (RE) play a major role in strengthening LE muscles. These also help in alleviating many workplace-injuries of LE muscles.

Keywords: Kinematic and Electromyographic, Muscles, Exercises

INTRODUCTION

Kinematic analysis of worker-movements during different work-activities helps researchers to observe the motion measurement to evaluate functional performance of limbs under normal and abnormal conditions. It involves special analysis of joint articulating surface movement, where generalized 3-dimensional, unconstrained rotation and translation are defined utilising the concept of the screw displacement axis. Knowing the floor geometry and smooth-tissue constraints, the motion of an articulating joint may be analyzed to offer fundamental statistics for lubrication and wear studies. In addition, with suitable numerical differentiation, velocity and acceleration may be obtained from the displacement statistics. Measurement techniques of human movement can be classified into three categories, viz., electric linkage technique, stereometric technique and biplanar roentgenographic method.

Kinetic analysis of human movement studies causes of the motion. As such force, moment of force, work, energy and power, impulse and momentum of various limbs during the movement are determined. Kinetic forces and moments are calculated from measured kinematic information (positions, velocities, and accelerations). This method is known as inverse dynamics, which is different from forward dynamics, used to calculate the acceleration resulting from a given force.

1.1 ELECTROMYOGRAPHY ANALYSIS :

Electromyographic (EMG) analysis during various RE help in finding out activation level of muscles of LE. It also helps in finding out which RE are better in terms of alleviating pain of concerning muscles or muscles group. Electromyography detects medical abnormalities, and recruitment order to analyze the biomechanics of muscles. It is assumed that activities eliciting higher EMG signal amplitudes create the potential for greater strengthening effects.

1.2 REHABILITATION EXERCISES:

Rehabilitation involves the process by which someone works to reduce pain or regain function after an injury, illness, or surgery. Rehabilitation exercises are important part of overall recovery, and help restore strength, range of motion, and endurance. The overall goal of RE is to restore someone to their former activity level and strength. Rehabilitation exercises are also crucial for preventing future injuries.

Therefore, strengthening of muscles or muscles-group requires careful planning and a systematic progression from less challenging to more challenging exercises. The demand of a particular exercise can be influenced by the plane of movement, effects of gravity, speed of motion, base of support, and type of muscle contraction. Researchers should consider these factors when designing and implementing strengthening exercises for the muscles.

2. RE AFTER ANTERIOR CRUCIATE LIGAMENT SURGERY

The anterior cruciate ligament (ACL) of occupational workers gets injured during activities involving fast movements of legs. Primary function of ACL is to limit anterior tibial translation when the quadriceps muscle group contracts to extend the knee. Previous studies have found that ACL-deficient individuals avoid use of the quadriceps in the injured limb as a means of limiting anterior movement of the tibia in the absence of a functioning ACL. This altered gait pattern has been found to persist in the period following ACL reconstruction surgery, and inhibits the ability of patients to return to full quadriceps strength during physical therapy.

2.1 LOCATION, STRUCTURE, AND FUNCTION OF THE ACL:

The knee is one of the largest joints in the body. It provides mobility and plays a major role in supporting the body during dynamic and static activities, which also contributes to making it the most complex joint. The knee complex consists of two main articulations: the tibiofemoral joint and the patellofemoral joint. The tibiofemoral joint is the interaction between the distal end of the femur and proximal end of the tibia. The patellofemoral joint is the interaction between the patella and the femur. Two fibrocartilaginous joint discs, called menisci, sit on top of the tibial condyles and act as shock-absorbers for the tibiofemoral joint. The meniscus also aids in distributing weight forces and reducing friction within the joint. Surrounding these bones is the joint capsule, which helps stabilize the knee. The capsule is a thin, fibrous sac of synovial fluid, and is attached to the condyles of the tibia and femur as well as surrounding muscles. This fluid helps lubricate the joint and allows for smooth motion. Ligaments in the knee are responsible for restricting or controlling unwanted motion. This includes excessive knee extension, adduction/abduction of the tibia, anterior/posterior motion of the tibia under the femur, medial/lateral rotation of the tibia under the femur, and combinations of anteroposterior displacements and rotations of the tibia. The medial (MCL) and lateral collateral ligaments (LCL), located on either sides of the knee, help resist hyperextension. The cruciate ligaments are positioned in the center of the knee joint within the articular capsule. The anterior cruciate ligament (ACL) connects the anterior portion of the tibia to the posterior portion of the femur by passing under the transverse ligament and attaching to the inner aspect of the lateral femoral condyle. The posterior cruciate ligament (PCL) attaches to the inner aspect of the medial femoral condyle and extends to the posterior portion of the tibia. (Levangie et al., 2001) The main structure of the ACL is composed of type I collagen bundles that are separated by type III collagen fibrils. The ACL possesses an avascular fibrocartilaginous zone with type II collagen located on the anterior side of the ligament which runs along the intercondylar fossa. It is believed that this fibrocartilaginous area arises from high shear and compressive stresses that occur when the knee is in full extension. These collagen bundles are grouped into two bands: the anteromedial band (AMB) and the posterolateral band (PLB), which attach to the anteromedial and posterolateral portions of the tibia, respectively. Changes in length of the AMB and the PLB describe the function of each band during joint motion. For example, at 0° of knee flexion, the AMB is at its shortest and the PLB is at its longest, indicating the AMB is lax, offering the ACL the least restraint to motion in this position, and the PLB is taut, offering the most restraint to motion in this position. The opposite is true when the knee is in 90° of flexion: the AMB is taut and acts as the restraining portion of the ligament, and the PLB is lax and does not act as a restraint. The main function of the ACL is to prevent anterior translation of the tibia on the femoral condyles. It also aids in restraining varus and valgus stresses within the knee, especially when a collateral ligament is damaged [10]. Injury to the ACL occurs mostly when the knee is flexed and the tibia is in some sort of rotation. The ligament appears to be in high tension as it wraps around the PCL during medial tibia rotation and as it stretched around the lateral femoral condyle during lateral tibia rotation. [7]Due to their positioning, the PLB incurs the most damage in knee extension, and the AMB in knee flexion[4].

Isokinetic stationary cycling is a common exercise in ACL rehabilitation.[20] Cycling is a closed kinetic chain exercise and is intended to help restore normal motion of the knee and improve range of motion. Isokinetic exercise is specifically defined as the shortening in length of a muscle or muscle group when it contracts at constant speed. To truly experience isokinetic exercise, opposing forces need to be able to quickly change resistance in order for the muscle to change its length at a constant speed throughout a muscle contraction. Some stationary bicycles that have programmable settings for isokinetic exercises can accomplish this type of activity.

3. LUNGE EXERCISE AS RE FOR MUSCLES ACTIVATION

Eccentric exercises are commonly used as a treatment for various muscle and tendon injuries. During complex motions such as the forward lunge, however, it is not always clear which muscles may be contracting eccentrically and at what time. Because this exercise is used during rehabilitation, the purpose of this investigation was to determine what type of contractions take place during two different types of forward lunge and assess the implications for rehabilitation. Eccentric training exercises with a specially designed training device are also used for prevention of hamstring injuries [2]. Given the success of these methods, it is desirable to find more exercises that could be used for the prevention and treatment of musculotendinous injuries and, in particular, exercises that do not require specialized equipment. Based on anecdotal evidence from athletes and trainers, these exercises may already be in practice. However, the effectiveness of some of these exercises, and what these exercises may achieve from a biomechanical perspective, is not always clear. One such exercise is the forward lunge, which is widely used in the athletic community during training and rehabilitation and requires no specialized equipment.

Forward lunge is also a closed kinetic chain exercise[15], in contrast to exercises commonly performed in isokinetic dynamometers such as leg flexion-extensions. In addition, forward lunges have recently been used to identify differences in the movement pattern of two different types of anterior cruciate ligament (ACL) patients [1]. It would therefore be beneficial to understand how variations of the lunge affect muscle activations and thus lead to its more appropriate use as a training and rehabilitation intervention.

4. KINEMATIC AND ELECTROMYOGRAPHIC ANALYSIS OF KNEE MOTION DURING RISING FROM A CHAIR IN STROKE PATIENTS

Rising from a chair is one of the most mechanically demanding functional tasks routinely undertaken during daily activities[5,16]. This movement is at least equally important to normal human function as walking because rising from a sitting position is commonly a prerequisite to the initiation of ambulation[21] and is considered a major determining factor for independence among elderly people and people with disabilities[9]. Impairments in this normal biomechanical movement may put a person at risk of falling[12,13].

Sit-to-stand (STS) movement was divided into four phases[19]: (1) Phase I (the flexion momentum phase), it begins with initiation of the movement and ends just before lifting the buttocks from the seat of the chair (lift-off). During this phase, the head, arms and trunk rotate forward around the pelvis and hips (toward flexion) therefore, displacing the body's centre of gravity (COG) forward generating upper-body momentum. (2) Phase II (the momentum-transfer phase), it begins with the initiation of vertical momentum as the buttocks are lifted off the chair. During this phase, the knee and hip extensor muscles show peak activity; as soon as; the lower extremities are loaded after seat-off. The centre of mass (COM) traveled anteriorly and upward reaching its maximal anterior point shortly after maximum dorsiflexion. There is concentric activity of the quadriceps muscle at the knee with eccentric activity of the biceps femoris (BF) muscle at the knee and gluteus maximus muscle at the hip. The peak muscle activity occurs during this phase, despite its short duration. Weakness of the quadriceps muscle and erector muscles of the spine, in particular, contributes to difficulties during this crucial phase[13]. This phase ends with maximum ankle dorsiflexion. 3) Phase III (the extension phase), it follows momentum-transfer phase and ends when the hips are in extension. This phase is characterized by vertical movement of the body to full stance. During phase III, the knee-extension and head-flexion motions are also coming to an end and the maximum COG vertical displacement is obtained as the hip, knee and ankle extensor muscles propel the body mass vertically[14]. 4) Phase IV (the stabilization phase), this phase begins just after the hip-extension velocity reached 0°/sec and continued until all motion associated with stabilization occurs. The separation between phase III and phase IV is not easily defined because the subjects in this phase normally experience some anterior-posterior (A-P) and lateral sway. Near the end of STS task, there is a decelerating force that causes brake for the translation of the body mass forward. This force is developed by the extensors of the lower limbs to achieve stability of the body in standing position[3].

STS movement is affected in stroke patients as a result of difficulty generating timing and sufficient force in the lower limb extensor muscles to propel the body vertically[17] balance impairment, disturbed muscle tone, lack of selective control and learned nonuse syndrome[12]. To overcome the difficulty and successfully execute the task, stroke patients modify their movement strategies by modifications in the displacement of the COM and by an asymmetrical weight-bearing pattern[18]. They make excessive trunk flexion to decrease the force exerted by the extensor muscles (specially, knee extensors), leaning toward the non affected side as they can develop more force to overcome the weakness in the affected limb [3].The patients also perform this movement slowly to overcome the impaired balance and to decrease the demand on the lower limb muscles[13]. Rising from a chair produces greater knee torques than gait or stair climbing[11,13] and requires large movement particularly of the hip and knee[8] that places more demands on the knee joint during this task[6]. Therefore, assessment of STS movement including lower limb joints especially, the knee joint (including kinematic and electromyographic assessment), should be included in routine functional assessment and in fall prevention programs. The purpose of this study was to conduct a kinematic and electromyographic analysis of knee joint motion during rising from a chair in both stroke patients (including the affected and non-affected sides) and normal healthy subjects.

5. CONCLUSION

LE muscles of occupational workers need special attention to do jobs that require common manual work-activities like pulling, pushing and lifting. Repetitive jobs and jobs requiring heavy load manipulation are common risk factors to cause or aggravate pain in LE muscles. It was observed in the first study that single-leg cycling is an effective exercise in strengthening quadriceps muscle group following ACL surgery. However, this study has its own limitations in terms of small sample size, sample range in terms of age of subjects. And inconsistency of results of kinematic analysis and EMG analysis. In the next study, it was found that quadriceps contract eccentrically during the first portion of a forward lunge. However, hamstrings have an isometric contraction during the beginning of the stance phase. The last study showed that stroke patients suffer asymmetrical movement pattern during rising from chair. EMG acyivation level of VL and BF muscles were disturbed. It may be concluded that RE can be useful in enhancing activations of concerning muscles of LE. Suitable RE can be designed to alleviate pain of such muscles during work-activities.

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