A COMPUTER SOFTWARE FOR ANALYZING MUSCULAR DYNAMIC WORK STATE OF LOWER LIMBS

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The study of the kinematics and kinetics changes of muscular work state during exercise, such as in muscular length and its variable velocity and the arm of muscular force, is very useful in the research of sports biomechanics, sports anatomy, sports physiology and athletic training. It can not only enhance exploring the principle of exercise and muscular working characteristics, but also help working on the project of muscular strength training. A three-dimensional musculoskeletal database of the lower extremities has been used for human musculoskeletal models, which helps estimate the muscle forces that generate and control movement. However, these models are sensitive to changes in musculoskeletal geometry. Thus a realistic geometry is one of the initial steps in their development. By measuring the lower extremity origin and insertion 3D coordinates of corpses, this research forms statistical regressive equation between parameters of anthropometry and origin and insertion coordinates. Furthermore, it utilizes the principle of multiple geostatics to develop a computer analysis software for dynamic muscular work state of lower limbs.

KEY WORDS: lower limbs, muscular function model, three-dimensional coordinates, segment independent reference frame, total station, synchronous test

INTRODUCTION: Study of muscles is a hot spot of sport biomechanics research. Laboratory studies are indispensable as well. Human motion studies by combining multiple synchronization and anthropometrics using computer-assisted modeling are an important means of laboratory studies in current sports biomechanics, but such studies are unbalanced. Although more and more attention is paid to the role of anthropometrical parameters in sports biomechanics, the existing research result cannot meet the needs of biomechanical studies. Muscle anthropometrical parameters (attachment point quantitative data) are key factors for the determination of muscle length, tension action line and muscle arm, playing an important role in the quantitative analysis of human motion kinematics and dynamics in the determination of muscle mechanics, in the establishment of the biomechanics model and in the quantitative evaluation of muscle functions.

METHODS:

Research for the three-dimensional coordinates of the attachments (origins and terminations) of lower limb muscles: The locations of idealized muscle attachments on the pelvis, two femurs, two tibias and fibulas, and two feet are accurately digitized for 10 cadavers specimens (8 male and 2 female). Origin and insertion centroid locations are used to represent idealized muscle attachment locations for 38 muscles and 43 muscle units (Muscles with broad origins were divided into two units) on each corpse side.

Either side of lower limbs of the cadaver specimens is marked with 99 landmarks for muscle origins and insertions (including substitute origins and insertions). In addition, 3 palpable landmarks are located on each segment (pelvis, femurs, tibias/fibulas, feet); the database can be used to living subjects when motion is measured. In total, data is collected from 29 landmarks per pelvis, 35 landmarks per femur, 34 landmarks per tibia/fibula, and 13 landmarks per foot.

Space three-dimensional coordinates of muscle attachments and skeletal morphological marker of lower extremities are scaled by close shot photography technology (the Total Station Method). As a new close shot photography measure technique, the three-dimensional coordinates of the landmarks are obtained with the total station.

Developing the four segments of independent reference frames of lower limb: This study describes segmental movement of lower limb with the rigid body azimuth generalized

coordinates; developes the four segment independent reference frames; manages to get the three-dimensional coordinate of the origins and terminations of Chinese people's lower limb muscles after analyzing the database with a computer program; the original coordinates of muscle attachments are transformed into segment reference frames.

Establishing the muscular function model of the lower extremity: The muscular function model of the lower extremity is established according to Bryant angle - which is applied to describe relatively change of the rigid body azimuth generalized coordinates; corresponding software - applied computer analysis system of the muscular function model of the lower extremity is developed. The software is used to assess the muscular function of the lower extremity when it is at standard anatomic position and to assess the muscular function change in the lower extremity according to the angle of joint.

Gait analysis with multi-equipment synchronization test: Take the gait analysis as an example to test the usability and reliability of the muscular function parameter of the model in body moving analysis and do the preliminary research of the muscular function model of the lower extremity with multi-equipment synchronization in methodology. The analysis software is made with rigid orientation coordinates as generalized ones. EMG, photographing, force platform are used to analyze the work state of seven lower limb muscles during normal gait.

RESULTS: Muscle origins and terminations are very valuable to determine the muscle length, muscle tension curve and muscle arm.

Three-dimensional data of the muscle attachment points of the lower extremity are highly accurate, which can be used as the databases of muscle attachment points of the lower extremity. The regression equation of three-dimensional coordinates of muscle attachment points is highly reliable, which can be used for living-body prediction.

The study does a synchronized and quantitative analysis of seven muscles in terms of muscular length, the arm of force, joint moment and EMG during normal gait.

DISCUSSION:

The Muscle Function Model of Human Lower Extremity: The study defines the concept of the human muscle function model, analyzed its core contents, and introduces its application into sports biomechanics study. The results show that muscle function model parameters are key factors for the determination of muscle length, tension action line and muscle arm, which play an important role in the quantitative analysis of human motion kinematics and dynamics to determine muscle mechanics, in the establishment of the biomechanics model and in the quantitative evaluation of muscle functions.

Function and Significance of the Mark of Muscles Origins and Terminations: The substitute mark of muscles origins and terminations are key factors for the determination of muscle length, tension action line and muscle arm, and play an important role in the quantitative analysis of human motion kinematics and dynamics, in the determination of muscle mechanics, in the establishment of the biomechanics model and in the quantitative evaluation of muscle functions. In this paper, we do the mark of muscles origins and terminations in lower limbs by experimental means. 38 pieces of muscles in lower limbs acting on hip, knee and ankle that have the substitute mark of muscles origins and terminations are 73.68%. The result reveals: the substitute mark of the muscles origins and terminations have important theoretical meaning and applicant value for determining muscle length, muscle tension curve and muscle arm and for the rational assessment of the muscular function.

The moving track of the knee cap: it is a hot topic for investigating quadriceps femoris. The variety of the trajectory of patellae is related to the movement of knee joint closely and works on the muscular length of quadriceps femoris affecting the arm of muscular force for hip and knee respectively. The specialized experiments of the length and the arm of quadriceps femoris are conducted by combining data provided by the research for the three-dimentional coordinate of the origins and terminations of lower limb muscles. Influence of the knee cap on calculating the length of quadriceps femoris and the arm force of the knee has been studied. The trajectory of patellae changing with the knee angle is a parabola. Patellae have

a great impact on knee joint arm and can extend the arm length to 2.5 times. Within the range of 90^0-0^0 knee stretch, that can get much longer.

Using "Bryant angle"of the rigid body azimuth generalized coordinates for describing the fixed - point motion of the segments of lower limb: Euler angle is currently used to describe hip joint motion of the human body by some experts and scholars, but the difficulty in mathematical calculation exists in its application and the related rotational axis is different from the elementary movement axis of the body. This paper introduces a new method describing the fixed-point motion of lower limb segments with Bryant angle, which can bring the rotational axis into correspondence with the movement axis of the body and avoid mathematical calculation difficulty of applying Euler angle to its description.

The iliopsoas for the function of the hip: because of its position in the body, muscle fiber alignment, the position related to the origins and terminations etc., the iliopsoas have its speciality and complexity. Up to now, we have not found the appropriate method to obtain the reliable fixed data from living body exercise process of the working muscle. The specialized quantitative analysis and assessment of the iliopsoas function are done by combining data provided by the research for the three-dimentional coordinate of the origins and terminations of lower limb muscles and according to the variety regulation of the muscle length and the arm of muscular force when the hip is at standard anatomic position and in the whole exercise range. The result shows: in regard to the machine axes of lower extremity (hip and knee joint center on-line), at standard anatomic position, the iliopsoas have the function of inside-revolve to hip joint.

Quantitative research for the muscular function of human lower limbs at standard anatomic position: Most lower extremity muscles have the strongest effect on frontal axis, sagittal axis takes the second place, the third is vertical axis. Because of the segment change, muscular function parameters to all these axis change correspondingly in quantity and in quality as well.

One of the functional characteristics of the hip joint muscle is that the value for the bogus arm of the muscular force is zero. It indicates that some muscles have been working all the time, some others stop working because of its function disappearing, the other muscles which don't work at initial stages begin to work, accompanying the movement of segment during thigh moving in whole range of the hip joint. This is the phenomenon of so-called "function compensation" of muscle in hip joint.

At standard anatomic position, the iliopsoas, pectineus, adductor longus, adductor brevis, lower part of adductor magnus have the function of inside-revolve to hip joint and gracilis has outside-revolve function. The upper part of the gluteus maximus can function as double joint muscle and has effect on knee joint bending and extending.

The synchronous test in dynamic movement of human with multiple machines: The sport biomechanics is an experimental science. Along with the technical development in science, more and more advanced and new techniques are applied to the biomechanical experiment research. The synchronous test in dynamic movement of human body with multiple machines is an important means in biomechanics research. The seven muscles in the treadmill test involve in the early stage of single leg support. The gluteus maximus does isometric contraction, and the pre-thigh and post-shank muscles make a concession. In the juggling and stretching stage, the post-shank muscles do restrained contraction. In the treadmill reset, the length of double joint muscles is largely affected by the knee joint extent. On the frontal axis, the pelvis (6^0) swinging is smaller than the sagittal axis (14^0) leaning and the vertical axis (13^0) rotating.

CONCLUSION: The experiment combined with the muscular function model of the lower extremity with multi-equipment synchronization proves the higher practicability and reliability of the muscular function. Once the applied computer analysis system of the muscular function model of the lower extremity is perfected, it will be more valuable in application and popularization.Using this software together with the above apparatus is convenient for analyzing dynamic work state of muscles quantitatively.

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