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ABSTRACT

Biomechanical aspects of preclinical descriptors of osteoarthritis

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The primary focus of the present study was to refine and evaluate a non- invasive technique which could quantify preclinical biomechanical descriptors of osteoarthritis in a patient population. One of the descriptors has been considered to be the stiffening of the subchondral bone which modifies the shock absorbing capacity of the joint. Results from 27 subjects tested with the accelerometer technique showed that the amplitude damping ratio obtained from the accelerograms of osteoarthritic patients were significantly lower than those of normal subjects. A Fast Fourier Transform analysis of the accelerogram from the anterior tibial tubercle indicated that osteoarthritic patients had higher frequency contents than those of normals. The "possible osteoarthritic group" revealed no evidence of clinical osteoarthritic changes; however, the biomechanical parameters measured indicated stiffening of the subchondral bone. The results of this investigation suggest the potential of this technique as a preclinical screening tool for identifying individuals at risk.

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BIOMECHANICAL ASPECTS OF PRECLINICAL DESCRIPTORS OF OSTEOARTHRITIS

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INTROOUCTION

It has been well established by epidemiologic data that 90% of individuals at age 40 years have radiological or clinical evidence of osteoarthritis. Current clinical methods of evaluation of this ubiquitous process have been demonstrated to be inadequate in detecting preclinical disease states. There currently exists a need for an alternative method of clinical evaluation which will identify individuals or populations at risk and also detect the development of preclinical disease. The purpose of this investigation was to refine and evaluate a non-invasive in-vivo quantitative technique initially described by previous researchers (1) which would satisfy the demonstrated requirement for a screening tool for osteoarthritis.

REVIEW AND THEORY

The transmission, absorption and attenuation of energy that intakes to the skeleton due to heel strike is an important component of bone physiology and pathology (1). The body's natural shock absorption system normally attenuates and dissipates the incoming force associated with the heel strike. This process is a natural and rational mechanism which protects the vital central nervous system structures. However, functional deficiencies of the natural shock absorbers in the human skeleton, i .e. subchondral bone, cartilage, muscle and other soft tissue structures, may pre-dispose the proximal joints to increased loading. Voloshin and Wosk (1) employed a technique that registers impact accelerations in bone during walking. With the use of a low mass accelerometer, impact accelerations may be registered in several points of the skeleton such as the tibial tuberosity, medial femoral condyle, sacrum and forehead. Knowledge of the accelerometer placement site along with the foot plate force will permit a quantitative determination of a joint's functional capacity to attenuate the incoming force. Deviation from available normal values of force attenuation in various joints would thus suggest a functional abnormality of the bone, cartilage or soft tissue, i.e. the natural shock absorbers of the human skeletal system.

METHODS

The twenty-seven subjects (mean age: 50.6 yrs ± 16.8 SD) who were evaluated by the accelerometer - technique were clinically classified as "normal", "osteoarthritic" or "possible osteoarthritic". The eleven subjects who had no history of knee pain, trauma, swelling or stiffness and had no evidence of knee pathology on physical examination, were assigned to the "normal" group. In addition the eleven patients who suffered from pain, trauma, swelling or stiffness in one or both knees were assigned to the "osteoarthritic" group. All eleven *of* these subjects were previously diagnosed by, their physician as having osteoarthritis. Five subjects . were assigned to the "possible osteoarthritic" group These individuals, although asymptomatic, were identified to be at high risk for development of osteoarthritis based upon the presence of one of the following factors: history of trauma, genetic susceptibility, occupation and age. Physical examination of this group revealed no evidence of early osteoarthritic changes.

Single axis accelerometers (Entran models) were attached below and above each knee on each subject (one on the anterior tibial tubercle and another on the lateral femoral condyle). The subject was instructed and trained to walk a figure "8" pattern on a 3.66 meter by 0.86 meter walkway at a speed approximately 1.66 meters per second. The amplified signal was recorded on a strip chart recorder, an FM instrumentation tape recorder and sampled (at 1000 Hz) by an analog to a digital convertor which was connected to a microcomputer. The data was analyzed utilizing a series of software programs developed at the Biomechanics-Ergonomics Research Laboratory of the Department of Environmental Health, College of Medicine, University of Cincinnati. The two parameters of the accelerogram evaluated were the absolute peak to peak values of the waveform produced by the heel strike and the frequency contents within the selected waveform. The amplitude damping ratio (ADR), i.e. the ratio of the peak value of acceleration at the anterior tibial tubercle to the peak value of the lateral femoral condyle was determined for each knee. In addition, a Fast Fourier Transform (FFT) analysis of a selected acceleration waveform associated with each heel strike was conducted. The first 51 harmonics of the FFT were determined. The parameters utilized in analyzing the first 100 Hz of the FFT waveform included: the number of peaks, the value of the frequency of each peak, the decibal (dB) down value for each pair of successive peaks, and the area under the FFT curve.

RESULTS AND DISCUSSION

The ADR for the eleven normal subjects was 1.39± 0.18 SD, while the ADR for the osteoarthritic group was 1.19 ± 0.10, which was statistically significantly different at $p < .0001$. Such decrement in shock absorbing capacity in the diseased group was expected. The occurrence of the number of peaks in the FFT waveform, up to 100 Hz, varied with the clinical condition. One of the preclinical descriptors of osteoarthritis has been considered to be the altered material properties of subchondral bone. The altered material property manifests itself as the stiffening of subchondral bone. Therefore, under impact loading of the heel strike, the accelerogram (at the anterior tibial tubercle) obtained from the osteoarthritic patients would show higher frequency contents than those found in the normals. All eleven normal subjects demonstrated one or two peaks, while all eleven in *the* osteoarthritic group were observed to have at least three distinct peaks in the high frequency range. The four subjects with mild osteoarthritis were noted to have three peaks. while four peaks were observed in the seven subjects with moderate to severe osteoarthritis. The frequency distribution of the peaks. up to 100 Hz. revealed higher frequencies in the steoarthritic group.

Comparison of the dB down for the first and second peak in the normal and eleven osteoarthritics revealed statistically significant difference at $p < 0.001$. A lower dB down in the osteoarthritic group implied higher (than normal) contributions by the second frequency peak in the FFT plot. The difference in the area under the FFT curve up to 100 Hz for'the eleven normal and eleven osteo- arthritic subjects was statistically significant at $p < .05$. The area values were higher for the osteoarthritic group than those of normals.

The effect of chronic. asymmetric. repetitive impulse loading to the subchondral bone of weight bearing joints appears to be a major factor in the development of osteoarthritis. The physiologic response of the bone to this loading results in stiffening of the subchondral bone. Spatial reorient- ation of the microtrabeculae, stiffening of the subchondral bone and the evelopment of stress concentrations precede the involvement of the overlying articular cartilage in the development of osteoarthritis. The results obtained from the present study are consistent with the expected data as related to the biomechanical properties of stiffened bone, i.e. decreased shock absorbing capacity and higher frequency contents on the impact accelerogram. The results of this clinical investigation do suggest that this quantitative non-invasive in-vivo technique for the identification of individuals or populations at risk for the development of osteo- arthritis and/or the presence of preclinical disease may indeed have merit.

REFERENCE

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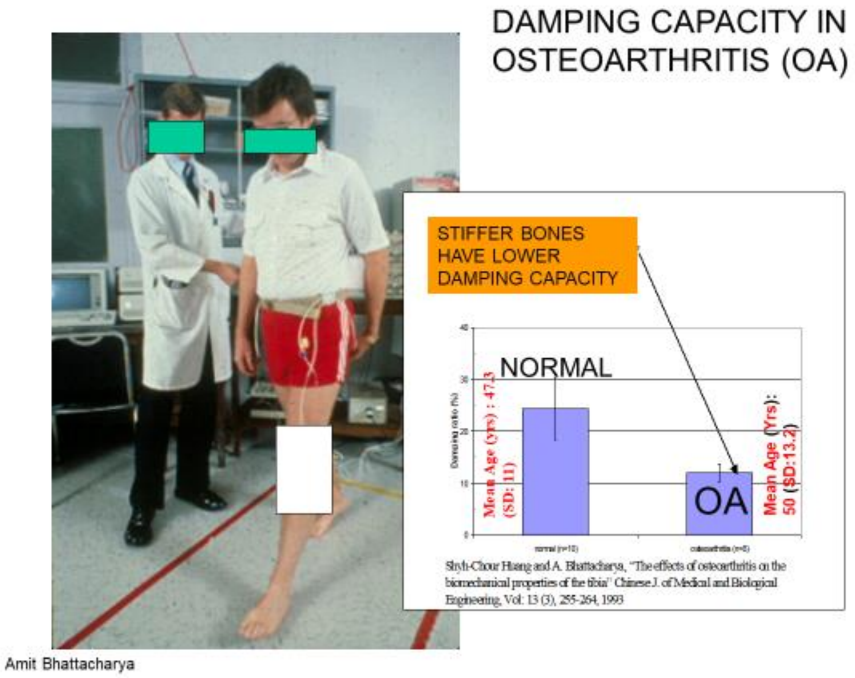

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