3D Reconstruction of Knee Motion by Videofluoroscopy & Videography with Orthogonal Cameras

Ledesma M R[1], Braidot A[2], Santos D[3-4], Simini F[4].

1 Universidad del Valle. Cochabamba, Bolivia. 2 Universidad del Nordeste Entre Rios, Argentina. 3 Departamento de Rehabilitación, HC, Montevideo Uruguay. 4 Núcleo de Ingeniería Biomédica, HC, Montevideo, Uruguay.

Introduction

Knee kinematics studies are growing in precision to help rehabilitation decision making in both sports medicine and orthopedics. In addition to well-known manual tests such as the Lachman procedure and KT-1000/2000 devices, we have suggested the clinical use of knee movement analysis estimating the center of rotation migration and the moment arm. Our **CINARTRO** method [1]-[2] is useful throughout training, but it is limited to the sagittal plane because it processes lateral images.

Research Question

We seek a method to measure the knee rotation using only one X ray imaging system.

Methods

By fusing two orthogonal video cameras with lateral videofluorscopy (VFC) during standard motor tasks such as stair climbing, we obtain a proxy of 3D representation of knee motion under load. Bony surface *repères* are necessary to perform the fusion of videography (VG) with VFC. The same markers must be visible in day-light and be opaque to radiation. Marker positioning (Fig. 1a) was selected to satisfy the rigid body assumption as well as being visible by cameras and X-rays [3]. Fig.1 b,c shows skin markers arranged as equilateral triangles, one on thigh, the other on shank.

Figure 1 – a) Videofluoroscopic image of volunteer climbing a step, b) and c) simultaneous orthogonal views of the same knee during the same step climbing task

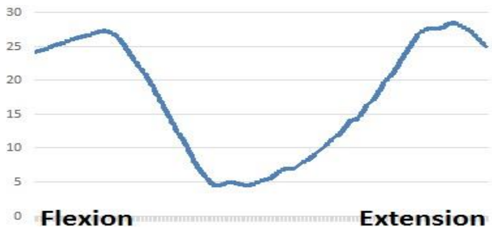

Figure 2 - Axial rotation of tibia along its longitudinal axis. From a partially flexed leg to full extension at the end of the step climbing

We positioned two video cameras on either side of the “intensifier-X-ray-tube” line of radiation, at right-angle. VG starts first, then a flash light is turned on/off by the operator, simultaneously with the instant the volunteer steps up. VG-VFC synchronization is performed during image analysis. VG frame rate was 120 frames per second and VFC 8 frames per second. We named this procedure **CINAR-3D**. Just before volunteer action, the set-up calibration consisted of a record of both VG and

VFC of a cubic phantom [4] [5]. Euler angles have been applied to describe the relative rotations in 3D space [6] in terms of orthopaedic angles (Lewis and Lew) [7].

Results

The first result of **CINAR-3D** is a representation of the rotation of the knee with only one X ray imaging. A preliminary result of rotation during stair climbing (Fig 2) is obtained by a VICON system: from flexion to extension (~70º) the rotation spans 24º.

Discussion

As part of the development of **CINARTRO** [1] to give clinicians a tool to record in a quantitative way the kinematics of the knee, we found that the lateral VFC gives only an approximation to this very complex movement, because it is intrinsically a 2D procedure, confined within the sagittal plane. Researchers and practitioners alike ask for additional information on the rotation to fine-tune their rehabilitation decisions and follow-up. But a second simultaneous X-ray is both expensive and doubles the ionizing radiation dose, despite it has been adopted [8]. This is why we decided to use simple cameras at a right angle to each other to add the 3D perspective to the movement analysis, which we now suggest as a new fusion of X-ray and home cameras. The key factor of **CINAR-3D** is the set of *repères* (VG & VFC) necessary to define the 3D orientation of frames. By including rotation in the appraisal of ACL-repaired knees, clinical decision making is enhanced because finer details of the functional behavior will be available.

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