3-D IMAGING APPLIED TO FOOT STRUCTURES IN WALKING: FIRST PHASE - BONE STRUCTURES

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INTRODUCTION

It is imperative for physical education students and coaches to develop a sound knowledge of human body structures as well as of the mechanisms permitting movements as a result of the interactions taking place between these structures. Such a comprehension of the human body requires a realistic 3-D representation of human structures in static positions as well as during movements (dynamics) and during mechanical stress applications (statics and dynamics).

Pedagogic and coaching experiments have shown that learning and training difficulties are frequently related to poor or inadequate 3-D visual representations of human body structures and movements. However, studies have demonstrated that computer assisted teaching using 3-D images can help mental visualisation as well as problem solving processes and can be used efficiently to complement other teaching techniques (Guy and Frisby, 1992; Michael and Rovick, 1986; Richards et al., 1987).

The main purpose of the study was to develop a low cost computer platform (using existing equipments and softwares) allowing 3-D imaging and movement animation of human anatomic structures. The main characteristics of such a computer platform should include: a) the capacity to generate 3-D "objects"; b) the capacity to animate these "objects"; c) facility of preparation and of presentation of these objects; d) low cost production.

Specific objectives of the first phase of the study were to illustrate plantar flexion, dorsiflexion, supination and pronation of the foot as a function of the walking cycle and to evaluate the influence of the use of this computer 3-D visualization assistance tool in a structural kinesiology course.

METHODOLOGY

Equipment and materials used included: a) a Commodore, Amiga 3000 T computer (180 Meg hard disk, 12 Meg RAM, Motorola 68030 - 25 MHz, Syquest copy system with 88 Meg cartridges); b) preparation software (DCTV, Imagine + Buddy System, D Paint IV, Art Department Pro, Audio Master IV and Quarter Back V5); c) presentation software (Amiga Vision, View, Pro Page and Page Stream).

Preliminary steps included the assembling of the production unit and learning of software. In order to create the "objects," the structured drawing programming technique was then selected among the available computer imaging techniques (which also included digitization and painting programming). Next, the complex joint structures including the lower parts of the tibia and of the fibula, the talus and the calcaneum bones, together with the other tarsal bones have been selected for static illustration of the ankle-foot joint structures as well as for visualisation of the dynamics of walking movements.

Anatomic and kinematic input data pertaining to the objects (joints structures) and to associated movements were then obtained from biomechanics literature (Czernieki, 1988; Root et al., 1977; Winter, 1991).

Procedures to create the basic 3-D "objects" included proper integration of reference points of ankle-foot structures viewed in three perpendicular planes, and the creation of the surface of the "objects" through the junctions of triangles determined by three adjacent reference points. Views from different angles were then developed; lighting effects (shadows) and surface colors and textures were added afterwards. At this point, triangles were "filled up" and sharp angles were rounded whenever necessary. The ankle-foot complex was then formed with the assembly of the individual "objects."

Movements of the ankle-foot complex were finally created through animation and proper editing and sequencing of the numerous images previously created. A total of 860 of these images were then selected and organized in a teaching unit, to demonstrate the anatomy of the ankle-foot joint, as well as the basic biomechanical aspects of normal walking. A human manikin walking movements and a "time code" were added to the images sequences and synchronized with the ankle-foot complex movements during the different phases of the walking cycles (Figure 1).

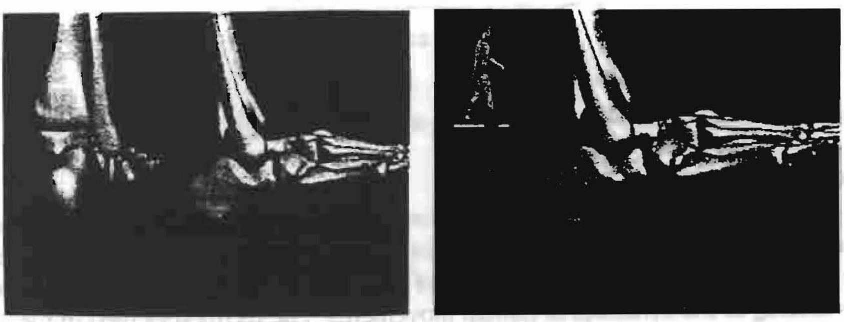

Figure 1. Animation modes and synchronization with manikin movement and "time code".

An in-class evaluation of the 3-D imaging product was then performed with physical education students in a structural kinesiology course. Subjects were assigned at random to two laboratory groups. The first group received traditional teaching (TT), while the second group was instructed through computer assistance teaching (CAT), using 3-D imaging of the ankle-foot complex to develop anatomical knowledge of bone structures and kinesiological knowledge of the walking cycle. Students were evaluated on answers to 24 questions before the session (Pretest), immediately after (Post-test # 1) and three weeks later (Post-test # 2).

RESULTS and DISCUSSION

Results (Figure 2) showed similar marked short term increases in anatomical and kinesiological knowledges in both groups. However, intermediate-term retention was much better with the CAT group: while the TT group demonstrated a 10.87% decrease in acquired knowledge, the CAT group exhibited only a slight 0.46% decrease over the same three week period. However, since these differences between the two groups were not statistically significant at the 0.05 level they have to be interpreted with caution. Such evaluations would have to be performed on larger groups and should include more questions. It would also be interesting to compare long-term retention in two such groups.

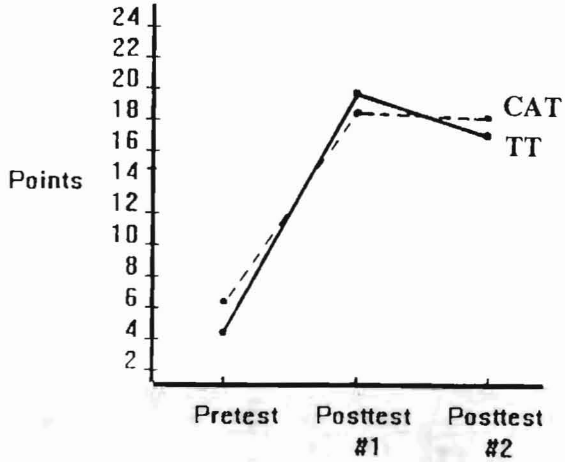

Figure 2. Results of TT and CAT groups on ankle-foot complex knowledge tests.

CONCLUSION

The first phase of the present 3-D imaging project has succeeded in adequately representing structures and movements of the ankle-foot complex. Such a 3-D representation could permit improved visualization of anatomical structures as well as a better understanding of the dynamics of human movements. The technology used in the present study could be applied to many structural complexes of the human body and to a variety of associated movements. A second phase of the study (presently under way) should include representations of ligaments, muscles and fascia, as well as illustrations of their roles during a variety of movements.

ACKNOWLEDGMENT

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