PEDESTRIAN IMPACTS WITH A PENDULUM IMPACTOR

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Abstract

The preliminary results of a biomechanics test series investigating adult pedestrian kinematics and injury response seem to show that 1) clinically observed lower limb injuries can be duplicated in a laboratory, and 2) lesser injuries may result with bumpers that permit longer duration impacts. The continuing experimental work will verify or refute these preliminary observations.

INTRODUCTION

The pedestrian bumper impact test series currently being conducted at The University of Michigan Transportation Research Institute (UMTRI) required some initial design investigation which defined subject pre-impact positioning, the impact target region, and two mechanical bumper models. Because the test series was being designed to use a cadaver model, inertial subject positioning was calibrated using both a 50 percentile adult dummy and a cadaver. Each of these developmental models was suspended from ceiling hoists via a parachute harness and a head harness threaded through a ropecutter over a load plate. Once released by the ropecutter these developmental "subjects" produced the hoped

for distribution of force through the feet for a long duration (greater than 100 ms). It was decided that the cadaver pedestrians in the upcoming study would be supported by such harnesses and released just prior to impact by the ropecutter.

An average bumper height was selected as the impact target region. A survey of the bumper heights in the UMTRI parking lot produced 47 cm as this average.

Two mechanical models would be investigated. One would be a solid half-cylinder representing a simplified bumper which would work well with high-speed X-ray cineradiography. The other would be a bumper removed from the front end of an automobile which should accurately represent the "real world."

The test hypothesis was that clinically observed pedestrian trunk and lower limb injuries could be reproduced in the impact laboratory using mechanical models and that the measured physical parameters (force, acceleration, and velocity) could characterize resultant injuries.

IMPACT METHODOLOGY

A test series using unembalmed cadavers is being conducted to investigate pedestrian impact response and kinematics secondary to bumper impact in a laboratory setting. The UMTRI pneumatic cannon accelerates a free-traveling ballistic pendulum which is fitted with one of two bumper models. A load cell is affixed to the column support of Bumper Model 1 to measure axial bumper force and the

impacting mass is 65 kg. The load cell is not used with Bumper Model 2 which has an impacting mass of 160 kg. Because of the difficulty of obtaining a force time-history at the impact contact point using Bumper Model 2, a general force is obtained by multiplying the mass of the pendulum impactor by its acceleration. The test subject is instrumented with 15 accelerometers rigidly affixed to the skeleton: 9 accelerometers are mounted as three triaxes on a pelvic plate and 1 triax is mounted on each tibia. The subject is placed in a striding position and is supported by a ceiling mounted parachute harness. In addition, the head is supported by a ropecutter which is released just prior to impact to permit normal inertial force distribution of the subject. Impact occurs from a lateral direction to a target region 47 cm above ground on the pedestrian subject. Tests are controlled by an electronic timing device and gross kinematic motion is documented by a high-speed X-ray or cameras on film. Induced damage is assessed by gross autopsy.

UMTRI PNEUMATIC BALLISTIC PENDULUM IMPACT DEVICE

The impact device consists of a 65 or 160 kg ballistic pendulum mechanically coupled to the UMTRI pneumatic impact device (cannon) which is used as the energy source. The cannon consists of an air reservoir and a ground and honed cylinder with a carefully fitted metal-alloy piston. The piston is connected to the ballistic pendulum with a nylon cable. This piston is propelled by compressed air through

the cylinder from the air reservoir chamber, accelerating the ballistic pendulum to become a free-traveling impactor. In tests made with Bumper Model 1, the 65 kg ballistic pendulum is fitted with an inertia-compensated load cell which is rigidly mounted to a support column behind the bumper (Figure 1).

BUMPER MODEL 1

The first bumper model is a solid half-cylinder mounted on a column support which is rigidly affixed to a load cell. Bumper Model 1 is approximately 13 cm in length with a 10 cm diameter. It gently slopes off to 35 degrees at its upper and lower edges. The UMTRI high-speed cineradiograph can be effectively used with this mechanical model.

BUMPER MODEL 2

The second bumper model is a grill and bumper section removed from a 1969 Malibu. It is roughly 102 cm in length and 48 cm in height. It slopes off about 10 degrees from the vertical midline. Its metal mass does not make it an effective mechanical model for high-speed cineradiography so high-speed photography is used with Bumper Model 2. It is mounted on a single column support on the pendulum (Figure 2).

SUBJECTS

The unembalmed cadavers being used in these tests are obtained from the University of Michigan Department of Anatomy. They are stored in coolers at 4 degrees

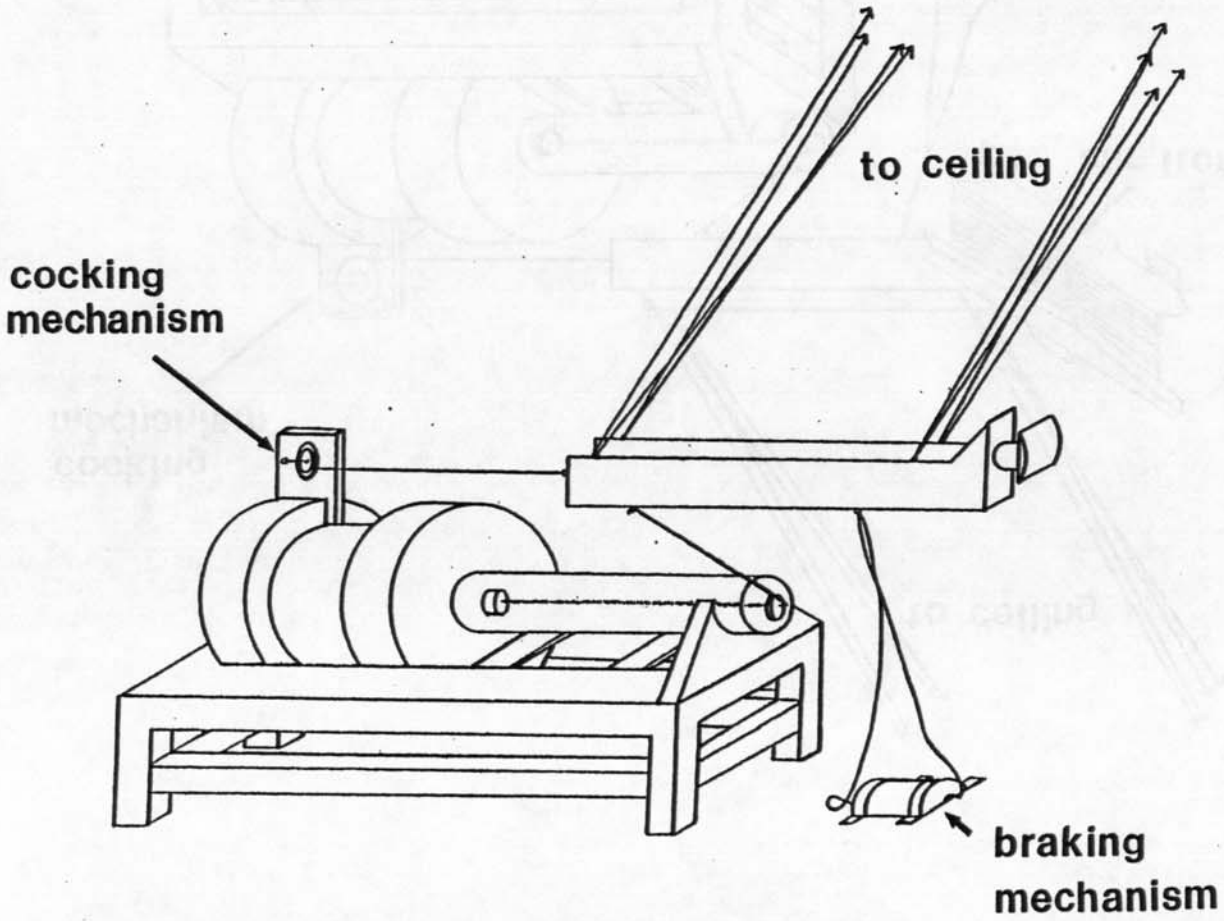

Figure 1 Bumper Model 1

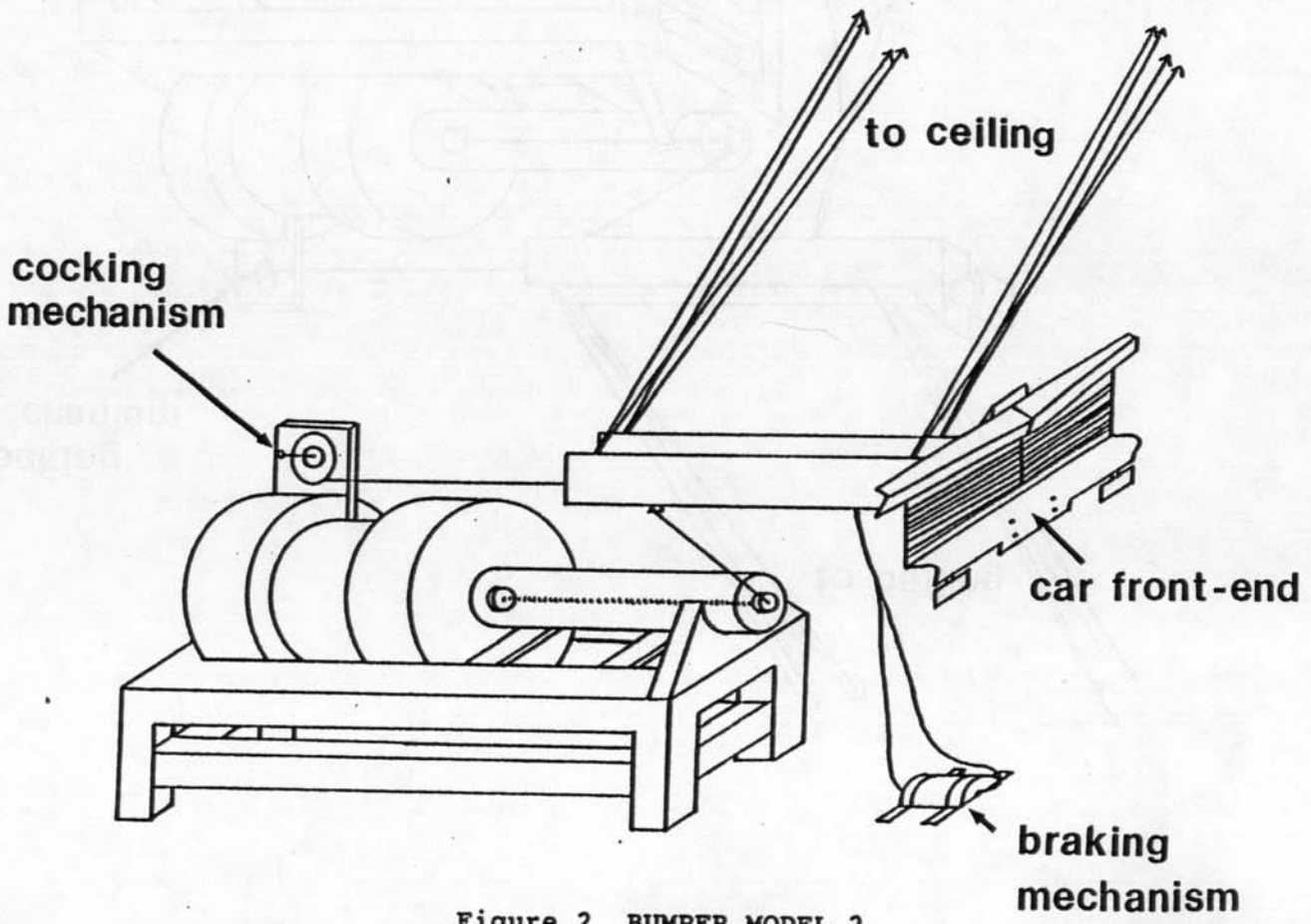

Figure 2 BUMPER MODEL 2

centigrade. Each cadaver is X-rayed as part of the structural evaluation for possible pre-test damage and surgical implants which would disqualify the cadaver from the test. Next, anthropomorphic measurements are taken. Then the cadaver is sanitarily prepared and surgically instrumented with accelerometer mounting platforms. The cadaver is dressed in a vinyl and cotton outfit, and is fitted with head and parachute harnesses.

In the impact laboratory, accelerometers and phototargets are attached. The subject is placed in a striding position, using paper masking tape which easily breaks away on impact, and is suspended by ceiling mounted hoists via the parachute and head harnesses (Figure 3). The impact target region is 47 cm above ground level. The subject is positioned so that impact will occur in a lateral direction. This simulates the most common pedestrian impact in which a pedestrian is struck laterally by a car preceding straight ahead.

ACCELERATION MEASUREMENT

Triaxial accelerometer clusters, affixed to the pelvis and tibias, document the kinematic response of the subject. Three triaxes are attached proximal to each other on a pelvic plate (Figure 4). One triax is attached to each tibia (Figure 4).

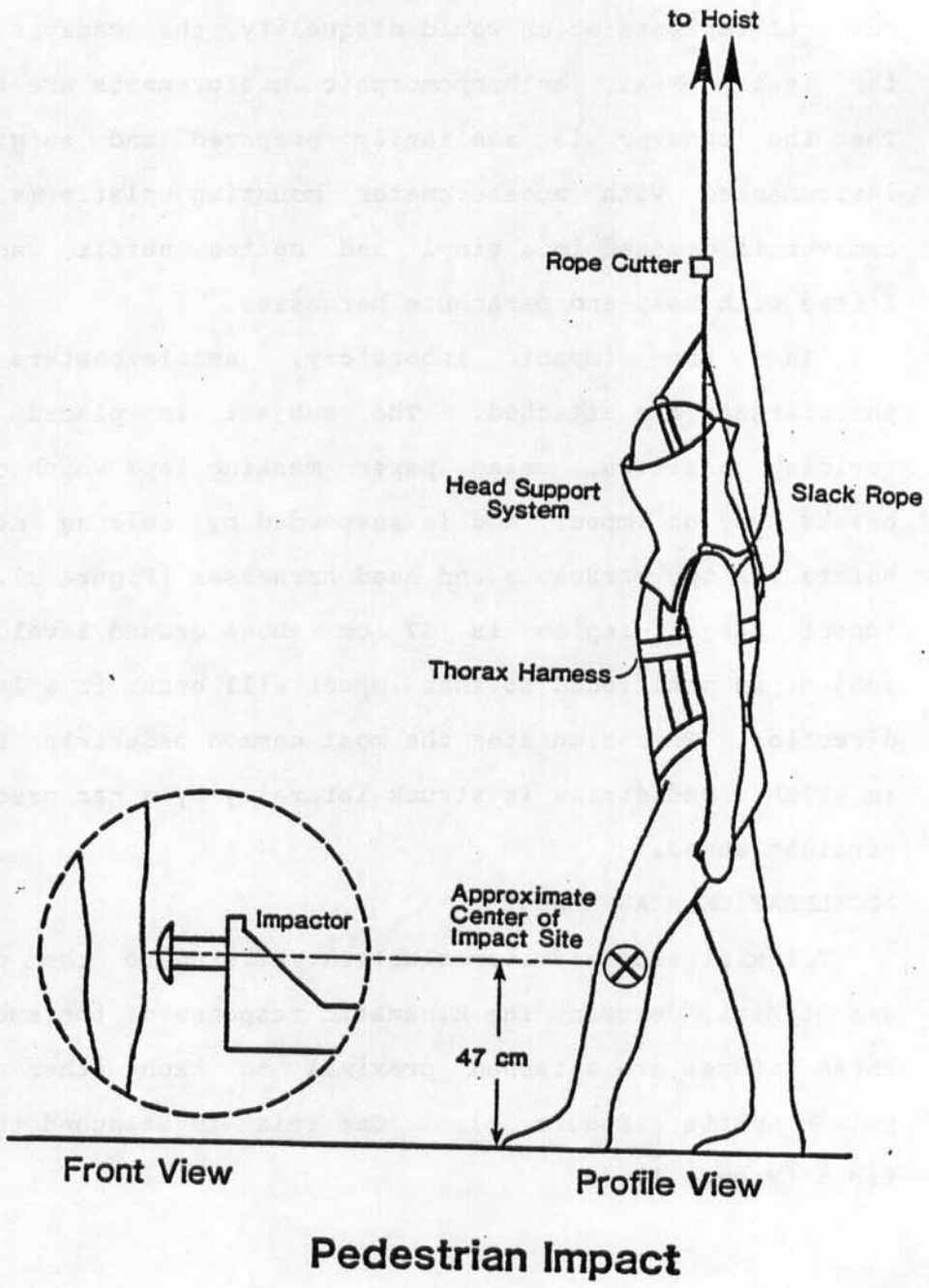

Figure 3 PRE-IMPACT SUBJECT CONFIGURATION

SURGICAL INSTRUMENTATION OF ACCELEROMETER MOUNTING PLATFORMS

Nine-Accelerometer Pelvic Plate - The nine-accelerometer pelvic plate (Figure 4) is installed in the following manner. Four lag bolts are screwed into the posterior-superior iliac spines, within the dimensions of the magnesium plate to be attached to the skeleton. Quick setting dental acrylic is molded around the bolts to form a securing medium, and the accelerometer plate is placed into the acrylic. In the impact laboratory, accelerometers affixed within a mount, such that orthogonal triaxes are formed, are screwed into the pelvic plate.

Tibial Platforms - An incision is made over the tibial site, the tissue is cleared from the bone and several small nails are hammered into the bone. Some tibial platforms have a central screw which is screwed into the bone. Dental acrylic is applied over the nails and a tibial platform is anchored in the acrylic. In the impact laboratory, a mounted accelerometer triax is screwed into each tibial platform.

IMPACT MOTION

Cineradiograph - The cineradiographic system allows minimally invasive viewing of internal anatomical structure in situ. In the case of a rigid structure such as bone, x-ray motion descriptors are selected based on anatomical landmarks, and motion is described similarly to that using standard photometric techniques.

Cameras - HyCam cameras operating at 1000 frames per

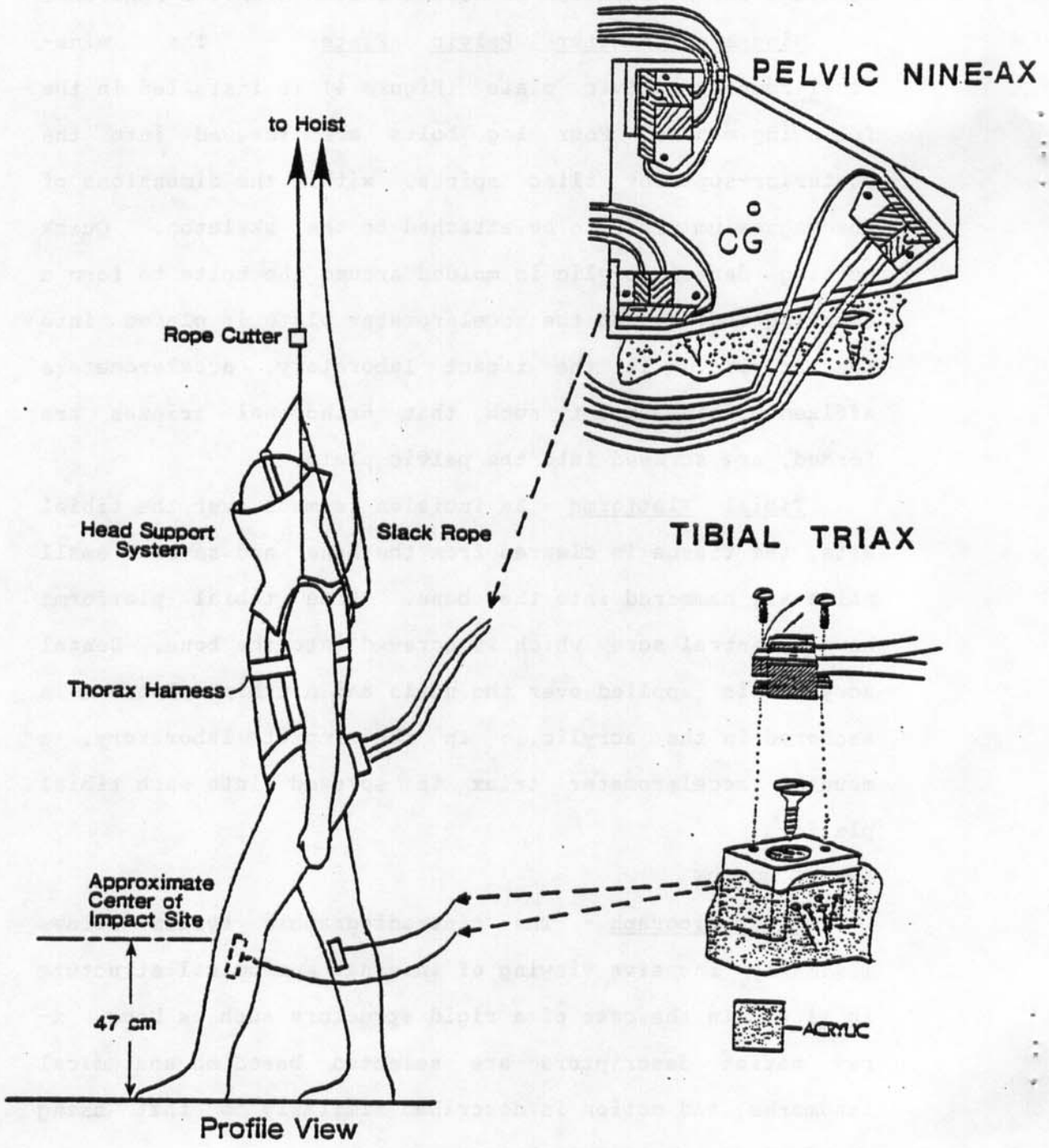

Figure 4 ACCELEROMETER MOUNTS

second record the impact from lateral and posterior views. Adhesive phototargets are attached to points of interest on the subject.

PRELIMINARY RESULTS

Using Bumper Model 1, bone fractures and torn cruciate ligaments consistently occur at 7 m/s in a 20 ms impact. Using Bumper Model 2 only cruciate damage occurs and the impact duration has lengthened to 80 ms or longer.

It may be that Bumper Model 2 strikes the pedestrian subject at the tibia and femur which is different than currently popular bumper-grill-hood systems that readily permit secondary and tertiary vehicle impact prior to ground impact. Bumper Model 2 may be less damaging than the currently popular bumper-grill-hood systems.

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