Instant Replay

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"A picture shows me at a glance what it takes dozens of pages of a book to expound."

—Ivan Turgenev, *Fathers and Sons,* 1862

It happened more than 20 years ago, yet the gruesome images remain vividly etched in the memories of every *Monday Night Football* fan who tuned in that night: the star quarterback desperately trying to release a pass as the relentless swarm of players collapses around him in a massive heap of muscles, pads, and helmets. The all-world linebacker clambering from the pile and frantically signaling for medical assistance. What had happened, we all wondered. What calamity could release such a powerful torrent of sympathetic distress from one of the most feared defensive players in the National Football League?

Within a few seconds, the reverse-angle instant replay illuminated the incident in eloquent detail. Lawrence Taylor's massive bulk had descended on Joe Theismann's fragile tibia, creating a textbook 3-point bending experiment for all to see. One did not need to be a mechanical engineer or even a rocket scientist to comprehend the conjunction of forces that conspired to snap that bone like so much kindling. The television broadcasters, themselves mesmerized, cycled through the video again and again as viewers stared in awestruck silence. Even today, duplicates of that infamous video clip circulate freely on the Internet in a macabre sort of perpetual instant replay.

Why does that snippet of videotape seize viewers in such a captivating grip? Certainly, one factor is the human fascination with mayhem and destruction that Hollywood filmmakers have learned to exploit so efficiently in their "action" extravaganzas. We are drawn to experiences that remind us that our bodies are delicate confections of flesh and bone that can be demolished with astonishing ease. But the "Joe Theismann broken leg video," as it is known in cyberspace, also appeals to a loftier dimension of human intelligence: our intellectual curiosity to understand how and why things happen.

In sports medicine, the drive to discover the how and the why of things has found a powerful expression in the quest to delineate the mechanism of ACL injuries. Research directed at this goal has included interviews with injured athletes, computer modeling, scrutiny of bone bruise patterns on MRIs, and laboratory simulation and analysis of movements thought to replicate injury situations. Although each of these methods is helpful in its own way, none of them involves direct examination of an actual injury. When we scrutinize a videotape, we do not need to speculate how closely our model simulates the mechanism of an ACL injury. We are witnessing a sequence of events whose outcome has been confirmed surgically.

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The obstacle to video analysis of ACL injuries lies not in establishing the verisimilitude of the episode but in extracting the required information from the available images. Video analysis of ACL injuries is possible because they occur in sports that are frequently videotaped, such as basketball and soccer. Because the tapes are primarily made for entertainment or coaching purposes, however, the resultant images are not ideal subjects for mechanical analysis.

One of the earliest video examinations of the mechanism of anterior cruciate injury was published by Wang et al in 1975.[6] At the time, many thought that ACL injuries chiefly occurred as part of a "terrible triad" caused by a direct valgus blow to the knee. Many clinicians were skeptical that "isolated" ACL tears could occur, a belief that, in that era before the widespread use of arthroscopy or MRI, led them to conclude that their patients had "only" sustained "a sprained knee." The authors' primary goal in publishing this article was to show that clinically isolated ACL injuries could indeed occur and to document one manner in which this might happen. John Marshall, the orthopaedic consultant to Cornell University in 1975, was called on to care for a linebacker who was "in pursuit of a ball carrier when he was violently blocked" by an opposing player who "struck the knee anterolaterally." Serendipitously, if that term can be used for an event that had such an unhappy consequence for the young athlete, the injury sequence was captured on the game films with a perfect clarity rivaling that of the notorious Theismann video.

The images in the case report of Wang et al are so informative because they reveal an ACL tear caused by a direct blow to the knee. It is now appreciated that lesions such as these are in the minority, with most ACL tears resulting from indirect trauma in which forces are transmitted through the internal structures of the unlucky athlete. Thus, casual inspection of video images that document ACL injuries is not normally so straightforward or enlightening.

"Mechanisms of Anterior Cruciate Ligament Injury in Basketball" by Krosshaug et al reports an ambitious effort to gather and analyze the videotapes of 39 ACL injuries. Some of these same authors have previously used video analysis to examine the general mechanisms of injury in soccer and specifically of ACL injuries in team handball.[2,5] In the current study, the authors examined a convenience sample of 39 videotapes of ACL injury situations submitted to them in response to a questionnaire distributed to college or professional basketball teams in the United States. Six international experts were selected to analyze the tapes.

The experts were asked to direct their attention to 2 distinct time points: the moment of the initial contact of the athlete's foot with the court and 50 milliseconds later. They were instructed to make a number of judgments: whether the injury resulted from direct contact with another athlete, the type of action in which the player was engaged, where the player's attention was directed, the athlete's foot placement, and the phase of the game at the time of injury. Although no measurement tools were provided, the experts

were also asked to estimate knee flexion-extension, knee varus-valgus, hip flexion-extension, hip abduction and adduction, approach velocity, and vertical velocity. Four of the experts were asked to assess whether the knee joint experienced a "valgus collapse" during the injury.

The investigators concluded that direct contact accounted for only 11 of the 39 injuries. In most of the other cases, however, they also felt that perturbation by another player was a contributing factor. Females demonstrated a higher mean knee flexion angle than did males at both time points and were 5 times more likely to exhibit a valgus collapse.

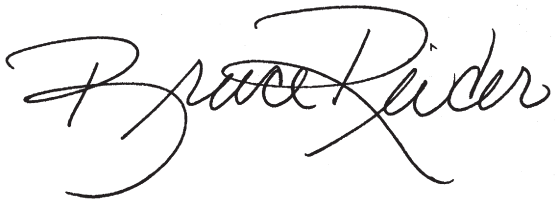
This study had many strong points. A large number of injury videotapes were examined independently by multiple experts. Many of the incidents were captured by 2 or more cameras whose images were then synchronized. The study articulated specific conclusions that might be helpful in designing injury prevention programs.

Any study of this type also has certain inherent limitations. The quality of the available images varied tremendously. It was felt to be good or excellent in only 6 cases but poor or impossible to judge in 17. This is disheartening because the comparatively confined playing surface of the court makes basketball a relatively ideal candidate for video analysis. In such a study, the limited data available from the images permit a general description of the situation at the time of injury but not calculation of the actual forces producing the ACL rupture.

Although the analysis was carried out by experts, it was perforce subjective and unblinded in nature. The experts' established perceptions could have influenced their interpretations of the images. Even experts, it seems, may be guilty of systematic error; a related study has shown that the same group of analysts consistently underestimated the amount of hip and knee flexion present in a videotaped noninjury situation.[4]

As other research published recently in *AJSM* has shown, implementation of an action plan derived from video analysis may not produce the expected reduction in injuries.[1] Ultimately, we may find that the injury situations identified by video analysis are unavoidable and that the key to prevention lies in the proper conditioning of athletes to withstand the jolts of vigorous competition.

Despite its practical limitations, video analysis should not be abandoned because it is our primary means of analyzing actual injury situations. Future improvements might include the installation of multiple high-speed cameras in a number of basketball arenas so that high-quality video of injuries can be collected prospectively. It is hoped that practical computerized analysis techniques can be perfected to remove the subjective element from video analysis.[3] If one picture is worth a thousand words, then moving pictures can speak volumes. To comprehend all they have to teach us, however, we need to develop a technological Rosetta stone to interpret them.



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