STUDY OF HIGH JUMP KINEMATICS USING MULTI-INSTRUMENT APPROACH

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Through the years biomechanists have made use of a variety of high technology equipment for their research. The complexity of this high technology has evolved to such an extent that anything can be measured, modeled and simulated. The coach, however, has not had adequate benefits from such technology. There is a need to simplify the high technology to provide alternate high technology approaches which an intelligent coach can explore and use to analyze an athlete's technique.

In describing a multiple-instrumentation approach to sport analysis, the example of high jumping will be used. The purpose of this high jumping research is to investigate from a comprehensive view the parameters which can be identified by a coach or biomechanist as being related to success and/or excess stress. The multiple-instrumentation approach was as follows: split-screen videography, 16 mm high speed dual-view cinematography (200 frames^{-sec}), force-time histories from an "AMTI" force platform, videography with digital timer, and force-time histories from split-medial/lateral insole transducers.

Based upon literature, and previous coaching and experimentation the following aspects of the high jump have been identified for analysis via the multiple-instrumentation system:

1. The foot plant with respect to foot placement and body lean.
2. The support-time during the take-off phase from heel-strike to toe-off.
3. The deformation of the foot during take-off in terms of medial-lateral stress, or pronation and supination of the foot.
4. Rotation and/or stabilization of the take-off foot during the arm and free leg swing.

SPLIT-SCREEN VIDEOGRAPHY

One can see the front view and the side view simultaneously to observe the foot placement from two planes. The sagittal plane view shows very little indication of body lean whereas the view from the frontal plane shows a definite body lean. The black and white images have low resolution. It is difficult to measure the support-time during take-off. The medial/lateral stress also can not be determined. However, the body lean and the sequencing of the free leg with the arm swing are clearly observed. One can qualitively analyze these segment movements during the jump. A coach can be taught to evaluate the amount and occurrence of "the blur in the image." It is also possible to see that the leg stabilization is dominant until the toe-off occurs. Body rotation then initates the rotation of the leg about its longitudinal axis.

VIDEOGRAPHY WITH DIGITAL TIMER

The camera was positioned to film the rear of the subject during the foot plant. From this position and with color image,phases of take-off execution are discernable. The foot seems to toe-in during the plant, although the lateral aspect of the heel contacts the floor first. It is possible to see that full contact occurs while the body leans away from the bar. During the support phase at the time extension is initiated, the heel lifts and the foot is medially rotated until toe-off. It is also possible to see that the free leg and the arm simultaneously begin an upswing movement. In addition, with the use of a digital timer one can easily measure the length of the support-time and the average velocity at the body segment of interest. Accuracy is to .03 seconds and is adequate for gross changes in performance, such as may occur with learning and with changes in height of jump.

FORCE PLATFORM

There is no doubt that the use of a force platform yields cónsiderable information. The actions of the take-off foot are the result of forces applied to the ground. The magnitudes, direction and sequences of these forces are critical in high jumping. This information alone, however, can not be assessed comprehensively in terms of mechanical skill unless it is combined with an analysis of a visual image of the spatial orientation of segments of the body. Nevertheless, one can analyze the production of the forces in terms of sequential patterning and magnitudes to compare with a normative template. Such a template would be obtained from data of many skilled performances. For this subject, the maximum vertical forces were as much as six times body weight at the impact while the maximum vertical forces were only four times body weight at the take-off. Other information to be obtained include the duration of the foot plant, the temporal parameters of each portion of the curve, the horizontal forces and all impulses. Not only are the vertical forces important to the stress on the foot, but one can not ignore the significance of force production along the horizontal axes (x, y). In this trial, the forces along these axes were not recorded.

The ground reaction force could be drawn as a vertical line upward. The body weight as a vertical line downward and the quasi-static moment at the joint and types of stress to the body parts estimated.

For high jumping the platform is a useful devise only if the conditioning program for the athletes includes moving the landing pit for each jumping trial of each athlete. Coaches will not consider this practical.

DUAL HIGH-SPEED CAMERAS

The first camera was positioned to film the subject in the frontal plane, the second camera was positioned to film the subject in the sagittal plane. Each camera was set to operate at 200 frames-sec. The application of high speed cinematographic techniques to this event is the most sophisticated and

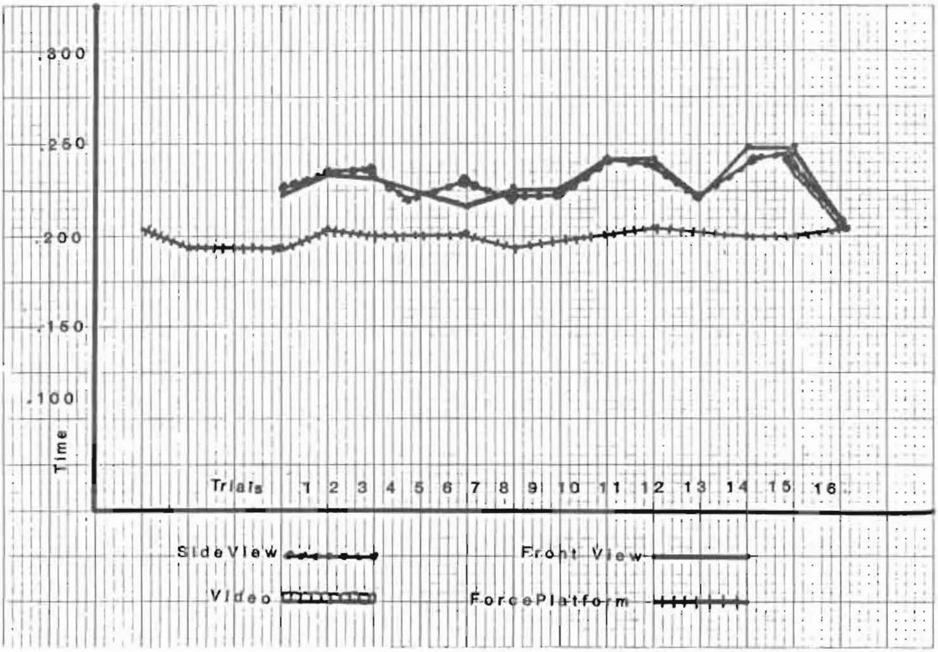
SUPPORT-TIME DURING TAKE-OFF

Trail	lbf fz	Platform	Front Cinama	Side Cinama	Video Digital	Split Screen	Insole Force	Height	
1	674	.205	-	-	-	-	-	4' 8"	clear
2	912	.196	-	-	-	-	-	4' 8"	clear
3		-	-	-	-	-	-	-	
4	803	.193	.221	.223	-	-	-	4' 8"	miss
5	793	.204	.236	.236	-	-	-	4' 8"	clear
6	778	.198	.236	.242	-	-	-	5' 0"	miss
7	765	.197	.226	.223	-	-	-	5' 0"	miss
8	913	.202	.221	.236	-	-	-	5' 0"	miss
9	819	.191	.226	.223	-	-	-	5' 2"	
10	909	.197	.226	.223	-	-	-	5' 2"	
11	-	-	.242	.242	-	-	-	-	clear
12	820	.205	.242	.236	-	-	-	5' 4"	miss
13	-	-	.262	.223	-	-	-	5' 4"	miss
14	877	.198	.247	.242	-	-	-	5' 4"	miss
*15	913	.196	.247	.247	.24	-	-	5' 4"	miss
*16	912	.205	.210	-	.21	-	-	5' 4"	miss

complex technology used in this multi-instrumentation approach. The advantage of film is that one can observe the movement in very slow motion and can, therefore, understand the activity better. The disadvantage is the cost and slowness in processing information. In jumping, the movement can be described using positional displacement, angles, and other kinematic parameters. In addition, calculation of kinetic parameters can be made. One can use film analysis in combination with force platform analysis to derive values of importance to coaches.

From the frontal view one can observe that the take-off foot steps out prior to the plant as the body leans away from the bar at the penultimate stride. The heel strikes first on the onset of the plant, and the foot is placed tangential to the path at the run-up. It appears that the lateral side of the foot contacts first. This is in agreement with the video image. At the full-foot-contact, it appears that the stress occurs at the medial side during knee flexion until the onset of knee extension prior to toe-off. At toe-off it appears that the lateral side supports the final thrust. After the take-off, the foot rotates outward following the turn of the body. The stabilizing effect of the take-off leg seems to be dominant until the toe-off. At the same time, the free leg and the arms begin their upswing.

From the sagittal view one can observe that the heel strikes first followed by a full contact, but no observation can be made to determine the medial and lateral deviation of the foot. Furthermore, the body lean seems to be in a posterior direction and not lateral as it really is. Three-dimensional analyses must be made of the performance. The new wireless computer-automated photo-optical systems, when the cost is within the realm of coaches' budgets, will be valuable to coaches.



FORCE-TIME HISTORIES FROM SPLIT MEDIAL/LATERAL INSOLE TRANSDUCERS

Since it was clear that the subject was using the right foot for take-off during the jumps, the force transducer insole was placed into the right shoe. A wire was run from the transducer to an amplifier that was attached at the waist. Finally, the cord was connected to an oscilliscope. The upper beam on the oscilloscope represented the lateral half of the insole and deflected upward with an applied force. The lower beam represented the medial half and deflected downward with an applied force. Using videography the deflection of forces from the oscilloscope could be permanently recorded. It was difficult to determine visually which trace deflected first, and it was difficult through "freeze framing" to calculate actual forces. When the storage function on the oscilloscope was used it was possible to display the entire support-time pattern. Coaches can readily evaluate the amount of force produced from either traces and the ratio of medial/lateral force. Theoretically, the stress placed on the foot could be postulated from these patterns as they relate to the total body movement.

Using the insole transducers with a Visicorder (high speed recorder), microcomputer telemetry are alternative methods for evaluating the stress on the foot during the plant and take-off.

CONCLUSION

Although the synchronization of several modes of instrumentation is imperative for specific analysis, the complexity and expenses of these multiple devices may be a barrier to coaches. Nevertheless, none of the instruments used individually would be sufficient for a complete analysis. In addition, identical data may be derived from multiple systems. For example, the support-time during high jumping may be determined from force platform, cinematography, force insoles, and videography. (Table 1 and Figure 1). Selection of the most convenient and inexpensive system may be adequate for coaching. Video data are similar to high speed film data.

Coaches must be interested in scrutinizing the mechanical and anatomial function of the foot during the high jumping. The use of the insole transducer combined with the oscilliscope and videography may be sufficient for doing so. These are both inexpensive tools and can be useful by the coach in identifying consistency (that is trial-to-trial variation).

Finally, the significance of biomechanical testing is dependent on the question encountered and/or the type of sport activity which is being investigated. These will determine which instruments would be applicable to predict the future development of an athlete. The coach and biomechanist could prioritize the questions. The biomechanist could review the literature and use complex high technology multiple-instumentation systems to determine a simplified approach for use by the coach. Specific kinematic values, types of movements, and positions at given instants during the performance can be given to the coach as criteria for comparison and charting progress of their athletes. Such an approach will result in the successful injection of high technology to the coaches.