P03-14 ID136

ANALYSIS OF THE JOINT ANGULES OF THE THROWING ARM IN JAVELIN THROW

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The purpose of this study was to explore the feasibility of using the panning method to analyze the joint angles of the throwing arm during the throwing of javelin. Two cameras (250 Hz) were set on the side and the back of the runway to analyze the athlete's throwing arm movemen with a panning method. Besides the joint angles of the shoulder (horizontal abduction/ horizontal adduction, abduction/ adduction, internal rotation/external rotation) and the elbow (extension/ flexion), the pronation/supination angles of the forearm, the ulnar/ radial flexion and the palmar flexion/ dorsiflexion of the wrist were also calculated . For each angle of the joints of the same trail of an athlete, the ICC (Intravlass correlation coefficients) of the two results from two different analysisers was bigger than 0.95 (P<0.01).

KEY WORDS: javelin throw, forearm, wrist, joint angle, elbow injury.

INTRODUCTION: The release speed of the javelin is the most important factors affecting the distance of the javelin flying, as much as 70% of the speed is developed in the last 0.1 second（Morriss & Bartlett, 1996）. In the last phase of throwing, the arm movements play an important role in raising the speed, and also play an irreplaceable role in the factors' control such as release angle, angle of attack and rotation.

The velocity of these joints center of the shoulder , the elbow and the wrist has already been researched （Antti Mero, Paavo V. Komi, Tapio Korjus, Enrique Navarro & Robert J. Gregor. 1994; R. J. Best, R. M. Bartlett and C. J. Morriss., 1993; Roger Bartlett, Erich Muller, Stefan Lindinger, Fritz Brunner and Calvin Morriss., 1996). The angles of horizontal abduction/ horizontal adduction at the shoulder, abduction/ adduction at the shoulder, internal rotation/external rotation at the shoulder, extension/ flexion at the elbow and extension/ flexion at the wrist (two dimension) could be analyzed (Mero et all., 1994; Liu, Steve leigh and Bing Yu, 2010). But no research has been found for the angles of pronation/supination at forearm, the ulnar/ radial flexion at wrist and the palmar flexion/dorsiflexion at wrist. As the throwing point on the runway is different for each player, even for the same player, to analyze the whole movement of the body, the cameras range is always set larger(8m: Mero et all., 1994). But the size of the captured image is relatively small, the image clearness of the forearm and wrist is not good enought to be used to analyze the details. The motion analysis is widely used for lots kinds of sports' movement analysis, but the price is high and the settings out of the track field is complex.

A javelin thrower asked to be analyzed the movement of the throwing arm of himself, to clearly recognize how to do the throwing action himself, and to find out the reseaon of his elbow injury and obtain some suggest to optimize the techniques to improve his performance. The purpose of this study was to explore the feasibility of using the panning method to analyze the joint angles of not only the shoulder and the elbow, but also the forearm and the wrist of the throwing arm in javelin throw, and give him suggestion to improve his performance.

METHODS: After ordinary warming up, markers were attached to both greater femoral trochanters, lateral superior tip of the two acromions. For the throwing arm, markers were attached to the olecranon of elbow, ulnar and radial styloid process and the back side of the 3rd metacarpo-phalangeal joint of the thrower.

The subject's movements of javelin throw were filmed with three synchronized video cameras. One camera (60 frames/s) was set on the side of the runway to analyze the whole body's movement, the other two cameras (250 frames/s) used to analyze the athlete's throwing arm's movement were set on the side and the back of the runway with a panning method.
The attempt with the best result was selected for analyzing from his 6 times throwings. The 3-D coordinates of the digitized points in time were obtained with Direct Linear Transformation (DLT) procedures. The location data of the markers was smoothed with the fourth-order zero-lag digital filter of the Butterworth type with optimal frequencies (Winter, 1990). Angular displacement of the joints of the shoulder, the elbow, the radia-ulna and the wrist was calculated with the projecting method (Wang, 2011) from the right foot touch down to release. The joint angles included:

θ1 (horizontal abduction/ horizontal adduction angle at the shoulder)
θ2 (abduction/ adduction angle at the shoulder)
θ3 (internal rotation/external rotation angle at the shoulder)
θ4 (extension/flexion angle at the elbow)
θ5 (pronation/supination angle at the radia-ulna)
θ6 (ulnar flexion/radial flexion angle at the wrist)
θ7 (palmar flexion/dorsiflexion angle at the wrist)

RESULTS: Figure 1 shows the joint angles of the throwing arm in the throwing.

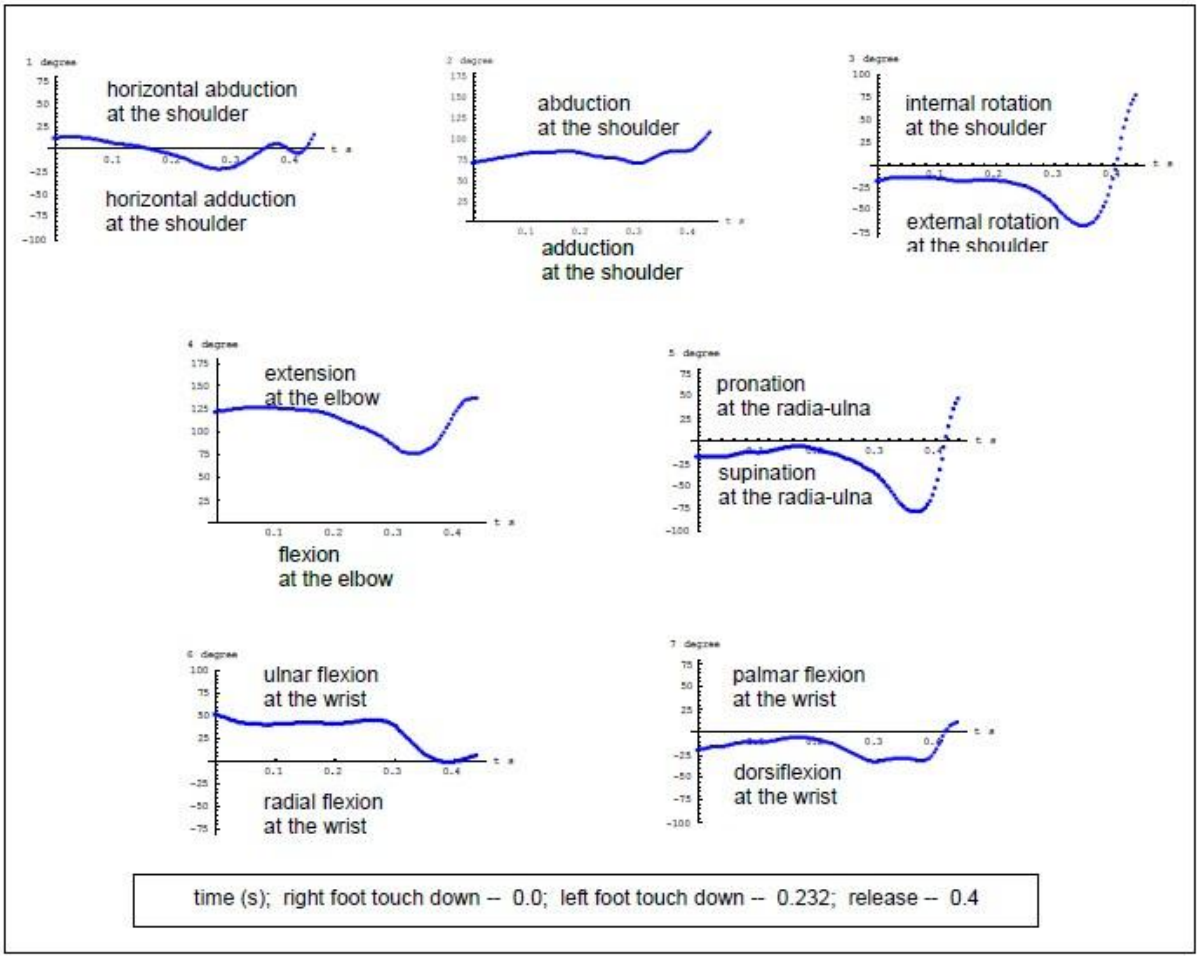

Figure 1: Changes of the joint angles of the throwing arm.

Joint angles of javelin throw for this athlete show substantially the same tendency of changes as baseball pitch (Sakurai, S., Ikegami, Y., Okamoto, A., Yabe, K., & Toyoshima, S., 1993).

Especially, for the anglesθ1, θ2, θ4 are very similar to baseball pitch. While, θ3 is about -20degree (baseball: about 30degree) in the preparing period. θ5 is about -15degree (baseball: about 90degree) in the preparing period, The extreme value of javelin throw is about -85degree (baseball: about -15~-30degree) just before the moment of release. θ6 is about 40degree (baseball: about 0) in the preparing period. The value decreased to about 0degree (baseball: rise to about 20degree) until the moment of release. θ7 is turn to about -10 from -20degree in the preparing moment, and then decreased to about -40degree before the moment of release (baseball: turn to about -40degree gradually from the preparing period to the moment just before release). Although the movement of javelin throw is a over hand throwing movement as the same as baseball pitch, the movement of the javelin throw has some distinctive characteristics due to the differences of the throwing objects (shape, gravity), existence of running approach, and the aim of the throwing.

DISCUSSION: With the panning method, it becomes possible to analyze the joint angles of not only the shoulder and the elbow, but also the forearm and the wrist of the throwing arm in javelin throw. Besides the joint angles of the shoulder (horizontal abduction/ horizontal adduction, abduction/ adduction, internal rotation/external rotation) and the elbow (extension/ flexion), the pronation/supination angles of the forearm, the ulnar/ radial flexion and the palmar flexion/ dorsiflexion of the wrist could be calculated. For each angle of the joints of the same trail of an athlete, the ICC (Intravlass correlation coefficients) of the two results from two different analysiser was bigger than 0.95 ($P<0.01$), and this calculation method of the joint angle is widely used in many kinds of sports' technical analysis.

Because of the characteristics of the shape of javelin, until about 0.2s before release, the shoulder maintain the gesture of external rotation, the forearm maintain the gesture of supination. And the wrist maintain the gesture of ulnar flexion until about 0.1s before release. These different characteristics compared with baseball show that it' s necessary to pay attention to use the exercise of throwing kinds of small balls as baseball in the training of javelin throw. On the other hand, this research increase the recognize of the throwing action: three movement of the shoulder (horizontal abduction/ horizontal adduction, abduction/ adduction, internal rotation/external rotation), one of the elbow (extension/ flexion), one of the forearm (pronation/supination), two of wrist (the ulnar/ radial flexion and the palmar flexion/ dorsiflexion).

For baseball pitching, the load of the ulnar collateral ligament (UCL) due to the varus torque may result in UCL injury (Fleisig, G, S., Andrews, J. R., Dillman, C. J., & Escamilla, R. F., 1995). Morrey and An (1983) showed in vitro that when the elbow was flexed 90° and a valgus load was applied to the elbow by the forearm, the UCL generated 54% of the varus torque for resisting valgus motion. While the elbow was extended (0°) , the value was 31%. The reason of action are considered that the shoulder turned to internal rotation quickly from the maximum external rotation at the state of elbow's flexion, these could lead the large varus torque and large load to UCL (Fleisig et al., 1995). In this case of javelin throwing, the action of shoulder and the elbow was as the same as baseball (Fleisig et al., 1995) or dodge ball (Zefeng Wang, Sakurai Shinji, Shimizu Takuya, 2010), the weight of the man javelin is more heavier than baseball or dodge(javelin: 800g, baseball: 150g, dodgeball: 300g), and the speed of javelin is very important for the javelin throw more than baseball or dodgeball, so the reason of the UCL injury of this javelin player maybe could considered that the action of the shoulder turned to internal rotation quickly from the maximum external rotation at the state of elbow's flexion, lead large load to UCL.Observing the changes of the angle of elbow of this player, the elbow was at the state of larger flexion from the right foot touch down, and keeped the same state until just before the left foot touch down. In order to reduce the load of the UCL of elbow, As a suggest to this javelin throwing player that to control his elbow straight from before right foot touch down and keep the elbow state as the possible upon before the right foot touch down. Since this was considered maybe could achieve the aim of reduce the load of the UCL of elbow, and as the same time could Increase working distance of throwing to javelin, in order to rise the release speed to improve

the flying distance of the javelin. Through the technical improvement training according to the given suggestion, the symptoms of the injury of the UCL of elbow have been improved, and his result of javelin throw was imcreased. This technical imprompment was also recognised by a professional coatch of javelin throw.
It's necessary for the photographer with panning method to pay attention to do some exercise to get the whole pictures of the movemont of the trunk and the throwing arm.

CONCLUSION: With the panning method, it is implemented to analyze the joint angles of not only the shoulder and the elbow, but also the forearm and the wrist of the throwing arm during javelin throwing. Besides the joint angles of the shoulder (horizontal abduction/ horizontal adduction, abduction/ adduction, internal rotation/external rotation) and the elbow (extension/ flexion), the pronation/supination angles of the forearm, the ulnar/ radial flexion and the palmar flexion/ dorsiflexion of the wrist could be calculated for to analyze the throwing motion of the throwing arm in javelin throw.

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