© by IAAF
21:2; 67-80, 2006

Biomechanical analysis of the javelin at the 2005 IAAF World Championships in Athletics

By Masatoshi Murakami, Satoru Tanabe, Masaki Ishikawa
Juha Isolehto, Paavo V. Komi, Akira Ito

ABSTRACT

Biomechanical research on the javelin throw has focused mainly on the release parameters. The purpose of this study was to clarify the relationships between the distance thrown and kinematic parameters of the throwing movement. The best competition throws of eight male finalists at the 2005 IAAF World Championships in Athletics and forty-nine Japanese male throwers were analysed. The authors confirmed the importance of release velocity and found certain characteristics of the throwing movement that enable the finalists at World Championships to obtain higher velocity than other throwers. These include a higher approach velocity and keeping the fore knee angle in the extended position during the final phase of the throw in order to convert the approach velocity into forward rotation of the trunk. They also found that during the forward rotation of trunk, top throwers keep both the elbow joint angle and the adduction-abduction angle of the shoulder small, which enables them to effectively transfer the internal rotation velocity of shoulder joint to the grip velocity.

AUTHORS

The authors work at the Osaka University of Health and Sport Sciences. During the 2005 IAAF World Championships in Athletics in Helsinki they were members of a scientific research project team led by Prof. Akira Ito.

Introduction

Biomechanical research on the javelin throw has focused mainly on the release parameters, including the initial velocity, release angle, attitude angle, attack angle and release height of javelin (BARTLETT R. et al., 1988; BARTLETT R. et al., 1996; HUBBARD M. and ALAWAYS L.W., 1987). These papers have argued that the most important factor for achieving a top performance is high velocity of the implement at the moment of release. However, the papers have not clarified the throwing movement in detail. MERO et al. (1994) investigated the body segment contribution to the throws of competitors at the 1992 Olympic Games in Barcelona. The authors compared the mean values of many kinematic parameters of the male and female finalists and found the differences within both groups. However, the relationship between the movements and distances thrown were not established.

The purpose of the present study was to clarify the characteristics of the throwing movement in the javelin by investigating the relationships between kinematic parameters of the movement and the distance thrown.

Methods

The javelin throwers analysed in this study were eight male finalists at the 11th IAAF World Championships in Athletics in Helsinki, Finland in August 2005 (hereinafter "finalists") and forty-nine Japanese male throwers (hereinafter "others") participating in four domestic athletics meetings.

The throwing movements were recorded by two video cameras set in the stadium. The camera speeds were 200 fps (for the meetings in Japan) and 60 fps (for the World Championships). The best performance of each of the throwers was analysed. These ranged from 45.25m (for one of the domestic Japanese throwers) to 87.17m (for the gold medallist at the World Championships). We recorded nine control points on the runway using two additional video cameras (distance in the throwing direction: 7m, vertical direction: 3.5m, lateral direction: 4m) for the following three-dimensional analysis.

Twenty-four reference landmarks on each athlete's body and three reference landmarks on the javelin were digitised and the three-dimensional coordinates were calculated using the direct linear transformation (DLT) method. The three-dimensional coordinates were smoothed using the 4th Butterworth digital filter and the cut-off frequencies, which ranged from 4.5 to 20.5Hz, were calculated by a residual analysis method (YOKOI T. and MCNITTY-GRAY J.L., 1990). With this data we calculated the following:

- Release parameters (initial velocity, release angle, attitude angle and attack angle),
- Approach velocity - calculated from the body's CM (Centre of Mass) immediately before the rear foot contact in the final phase of the throw,
- Pull distance and pull time (distance and time of javelin movement from the rear foot contact to javelin release, respectively),
- Joint and segment angles at the moment of release.

In addition, we calculated the theoretical distance for each of the throws studied using the following estimate equation:

$$D = \frac{1}{g} v \cos\theta \left[v \sin\theta + \sqrt{(v \sin\theta)^2 + 2gh} \right]$$

where
D: the theoretical distance
υ: the initial velocity at the moment of javelin release
θ: the release angle
g: the acceleration due to gravity
h: the release height

The significance level was set at 5% (Peason's product-moment correlation coefficient). The symbols ● and ○ in all figures indicate the "finalists" and "others", respectively.

Results

Release parameters, pull distance and time, and approach run velocity

Although a significant positive correlation was observed between the initial velocity of the javelin and the distance thrown ($r = 0.889$, $p < 0.001$; Figure 1), non-significant correlations were obtained between the distance thrown and the release angle, attitude angle, attack angle and release height (Figures 2, 3, 4 and 5, respectively). A significant positive correlation was observed between the distance thrown and the calculated theoretical distance ($r = 0.909$, $p < 0.001$; Figure 6).

The pull distance was correlated positively and significantly with the distance thrown ($r = 0.426$, $p < 0.01$; Figure 7), but the pull time was negatively correlated ($r = -0.418$, $p < 0.01$; Figure 8).

A significant positive correlation between the distance thrown and the approach velocity was obtained ($r = 0.742$, $p < 0.001$; Figure 9).

Segment angles of the throwing arm at the moment of javelin release

Although significant negative correlations were observed between the distance thrown and both the elbow joint angle ($r = -0.484$, $p < 0.001$; Figure 10) and adduction-abduction angle of the shoulder joint ($r = -0.474$, $p < 0.001$; Figure 11), the horizontal adduction-abduction angle of the shoulder joint showed a non-significant correlation with the distance thrown (Figure 12).

Angle of trunk and front leg knee joint at the moment of release

Although a significant positive correlation was observed between the distance thrown and the forward trunk rotation angle ($r = 0.463$, $p < 0.001$; Figure 13), a non-significant correlation was observed between the distance thrown and the lateral rotation angle of the trunk (Figure 14). The distance thrown and the front leg knee joint angle showed a significant positive correlation ($r = 0.310$, $p < 0.05$; Figure 15).

Discussion

The values of the release parameters for the "finalists" were consistent with those of male throwers reported by MERO et al. (1994). Although a significant positive correlation was observed between the distance thrown and the initial velocity, non-significant correlations were observed between the distance thrown and the release angle, attitude angle, attack angle and release height. These results are consistent with other studies that indicate the velocity of the javelin at release is the most important factor for achieving a high performance (GREGOR, R.J., 1985; BARTLETT, R. et al., 1988). A significant positive correlation was observed between the distance thrown and the theoretical distance. Almost all the performances by the "others" were lower than the theoretical distances we calculated. These results suggest that environmental factors (e.g. weather, atmospheric pressure, atmospheric temperature, wind direction and speed, etc.) interfered with the flight of the javelin. However, despite the heavy rain during the World Championships final, the "finalists" achieved distances that were almost the same or greater than the theoretical distances. These results suggest that they have a highly developed ability to receive environmental information and react effectively to it.

Compared to the "others", the "finalists" showed higher approach run velocity, longer pull distance and shorter pull time. The results suggest that the "finalists" perform the large and fast throwing motion during the final phase, and that this motion is crucial to performance in the javelin throw.

The "finalists" had a tendency towards a decreased elbow joint angle at the moment of release by a value similar to that reported by MERO et al. (1994). Theoretically, the internal rotation velocity of the shoulder joint can be transferred to the grip velocity most effectively when the elbow joint is at a right angle. In other words, having their elbow joint angle nearer to the right angle indicates that the "finalists" performed a more efficient movement to transfer the internal rotation velocity of the shoulder joint to the initial javelin velocity than the "others".

Although coaches generally instruct throwers to keep the elbow high (to keep the shoulder joint in an abducted position) and extend the elbow joint at the moment of release, the present results suggest that these instructions should be reconsidered.

Further, the finalists had a tendency towards an increased forward rotation angle

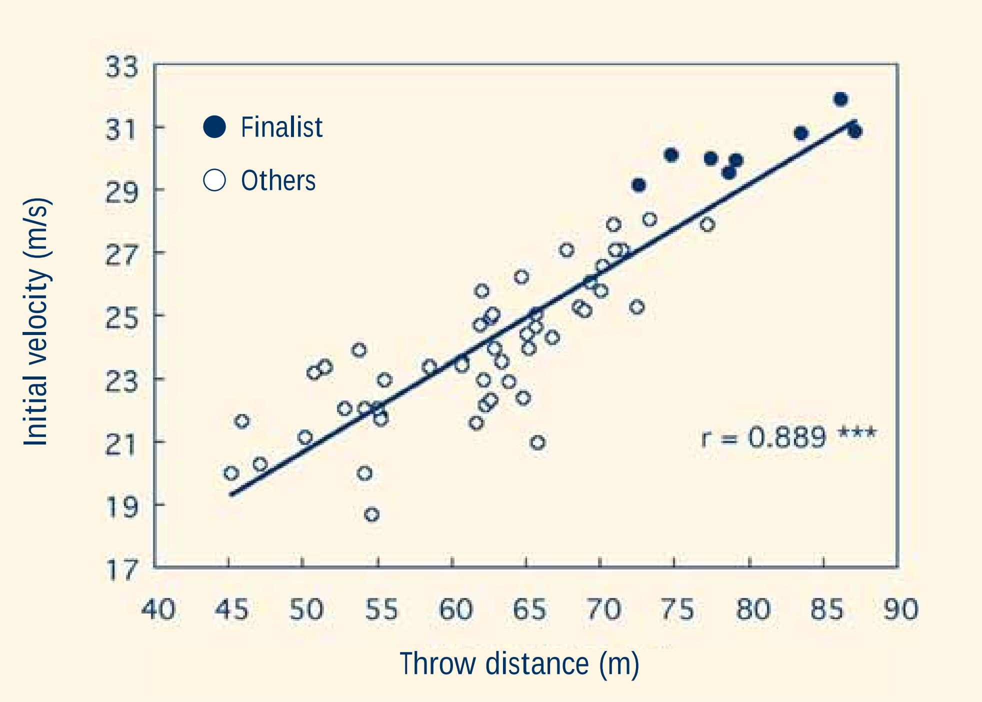

Fig. 1. Relationship between the throw distance and initial velocity.
***; $p < 0.001$

of the trunk and an extension of the front leg knee at the moment of release. The present results support the general coaching instructions to keep the knee in the extended position in order to convert the approach velocity into the forward rotation of the trunk most effectively.

Conclusion

The purpose of this study was to clarify the kinematic characteristics of the javelin throw movements of by studying the finalists of the 11th IAAF World Championships in Athletics and 49 japanese throwers:

Our findings confirm that most important factor for achieving a high performance in the javelin is the release velocity. The characteristics of the throwing movement of the finalists at World Championships that enable them to obtain a higher release velocity than other throwers are as follows:

- They approach with faster velocity and keep the fore knee angle in the extended position during the final phase of throw to change the approach velocity into the forward rotation of trunk
- During the forward rotation of the trunk, they keep their elbow joint angle small and adduction-abduction angle of the shoulder also small to be able to effectively transfer the internal rotation velocity of the shoulder joint to the grip velocity.

Please send all correspondence to:
Akira Ito
aito@ouhs.ac.jp

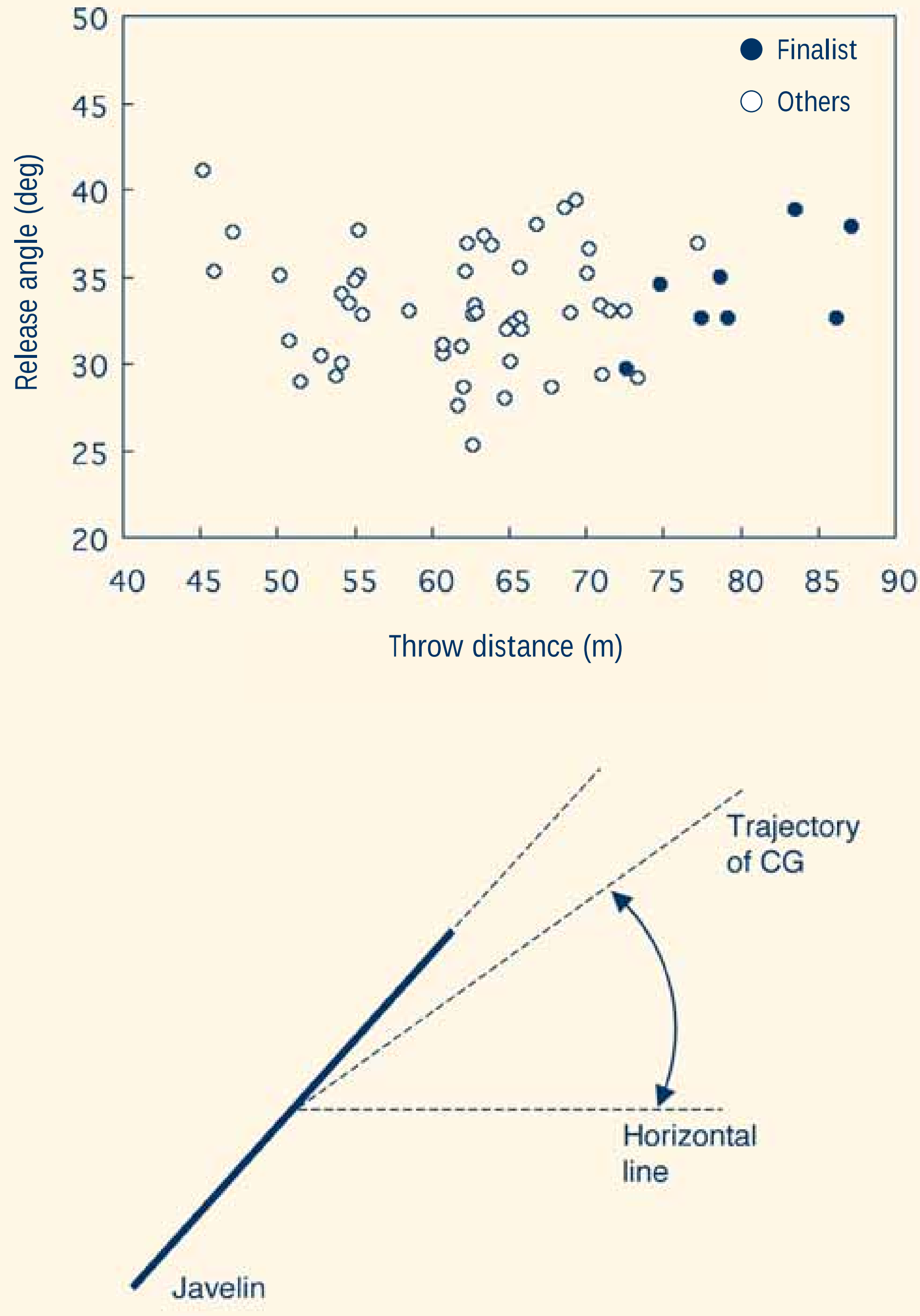

Fig. 2. Relationship between the throw distance and release angle.

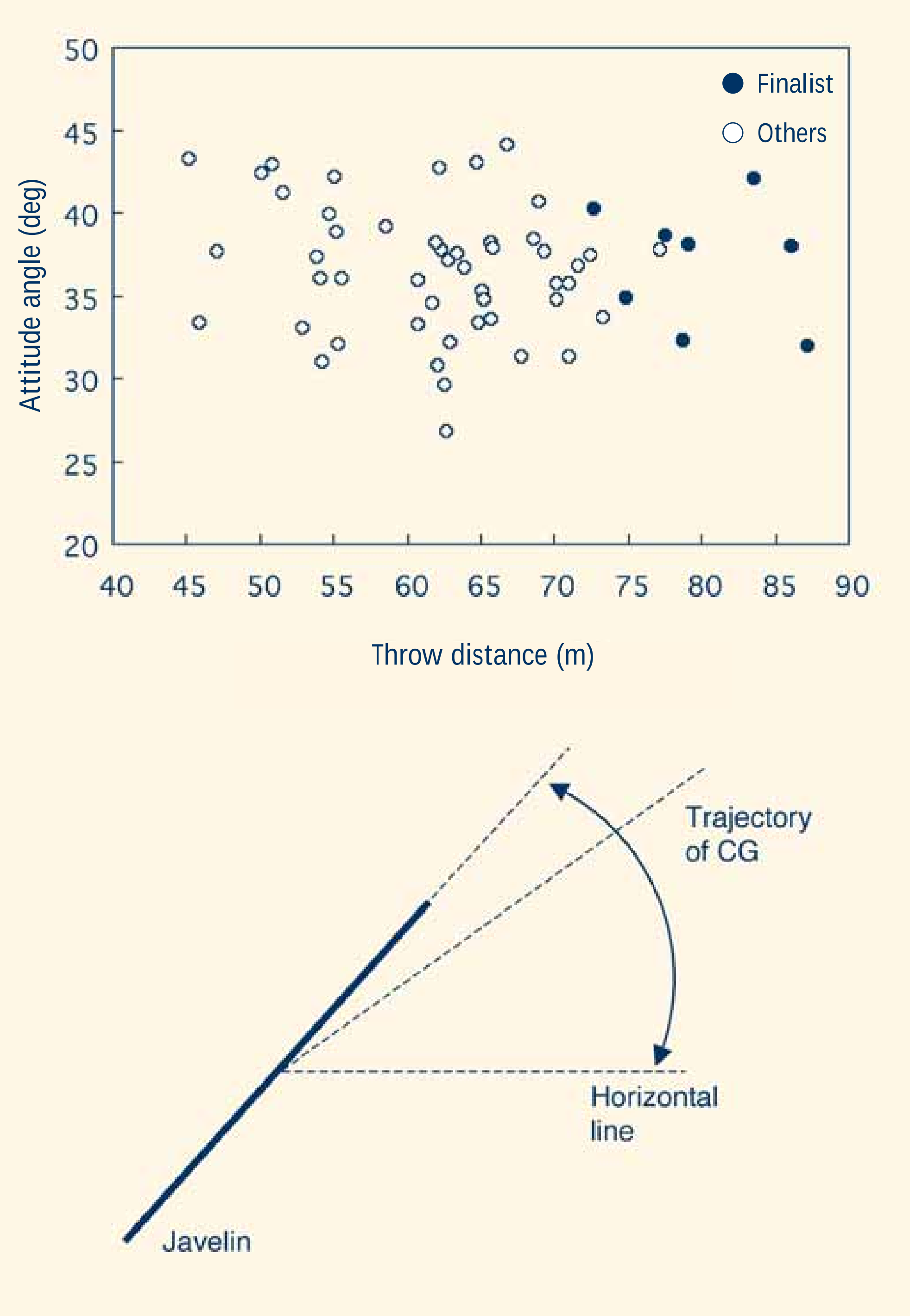

Fig. 3. Relationship between the throw distance and attitude angle.

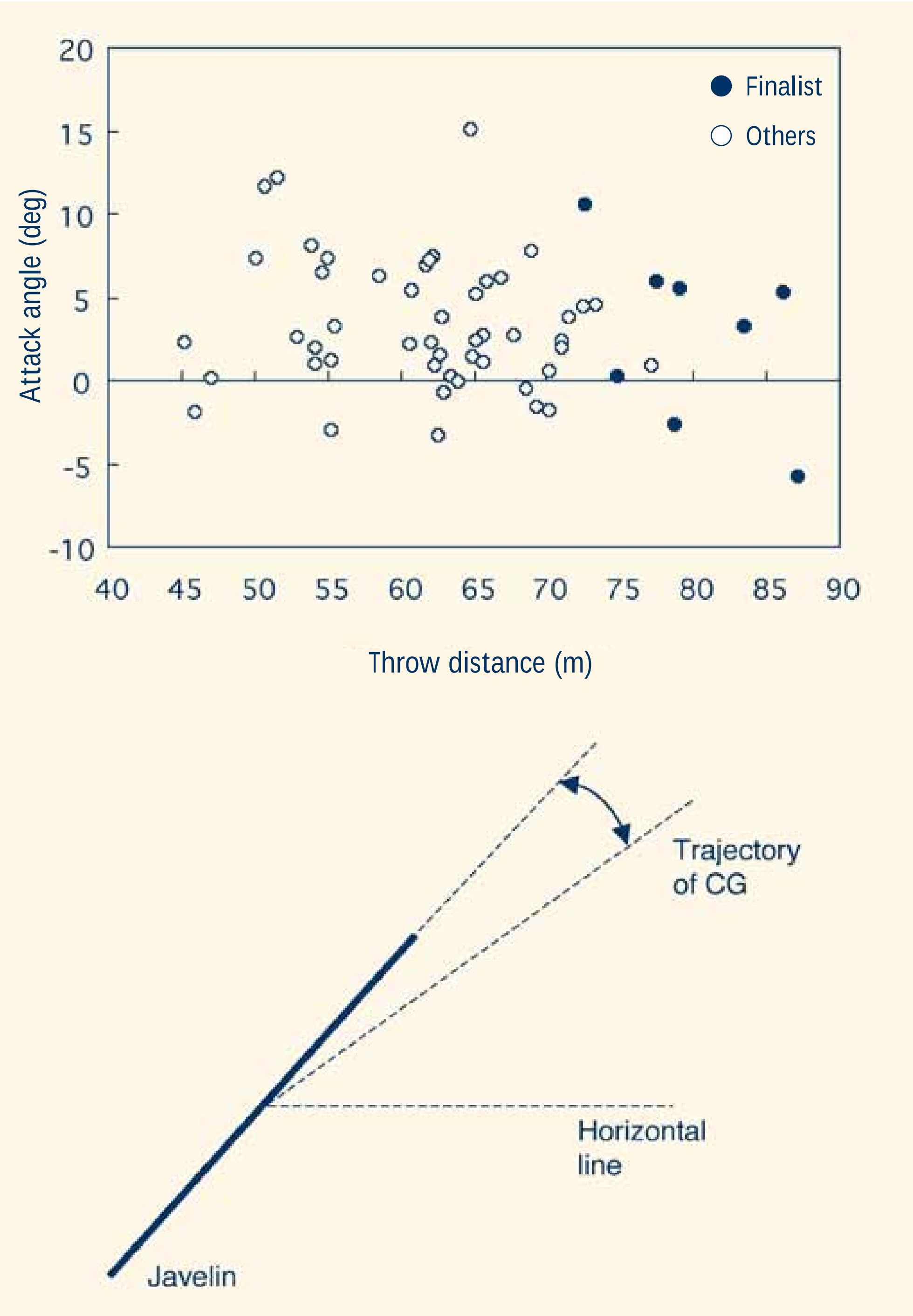

Fig. 4. Relationship between the throw distance and attack angle.

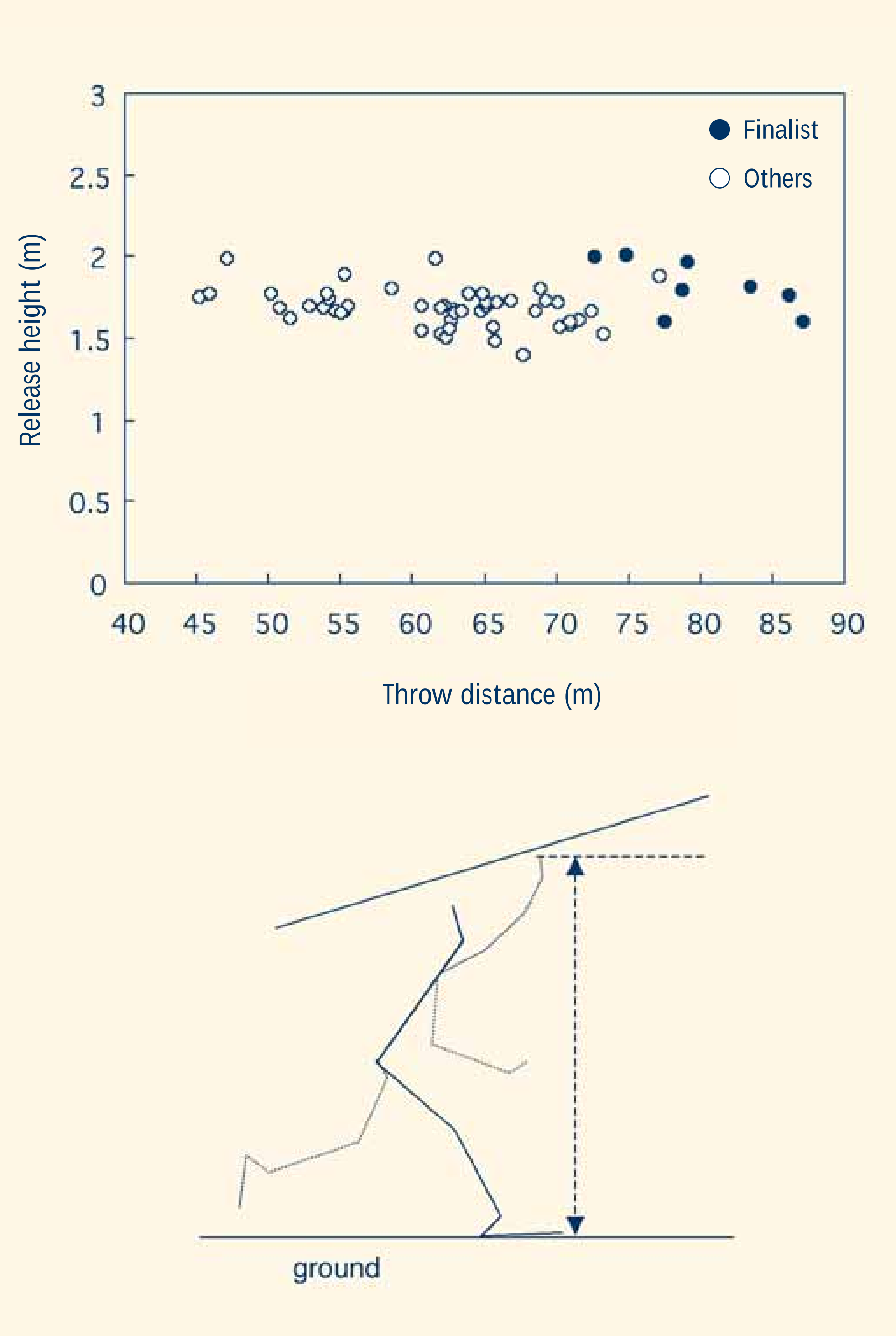

Fig. 5. Relationship between the throw distance and release height.

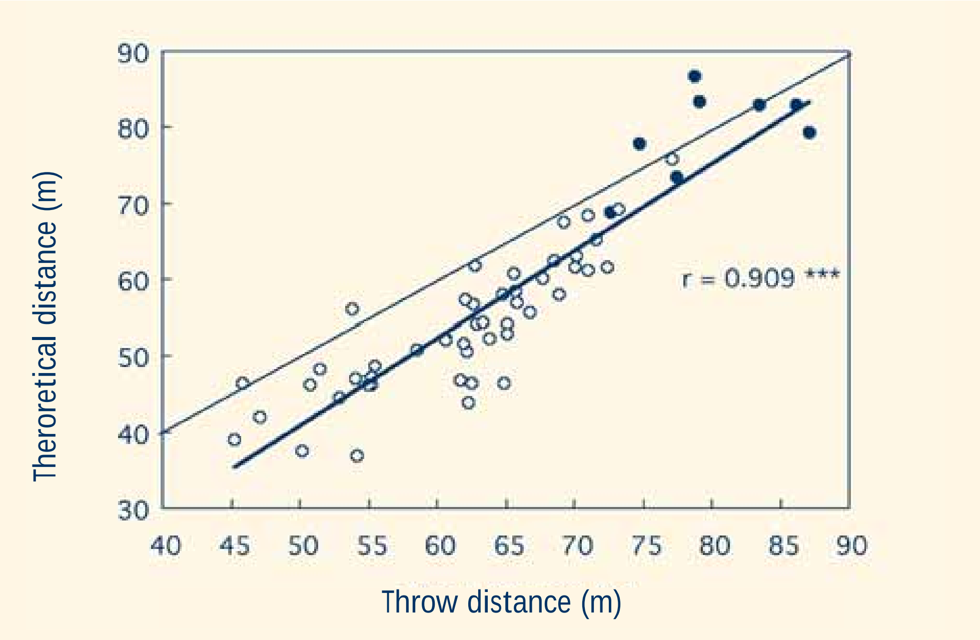

Fig. 6. Relationship between the throw distance and theoretical distance.
***; $p < 0.001$

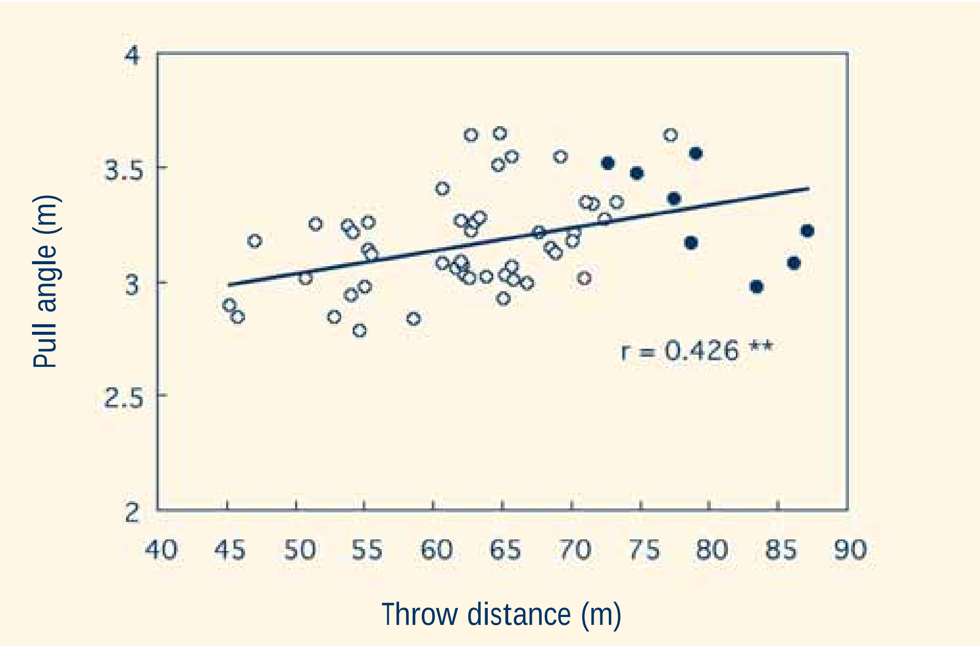

Fig. 7. Relationship between the throw distance and pull distance.
**; $p < 0.01$

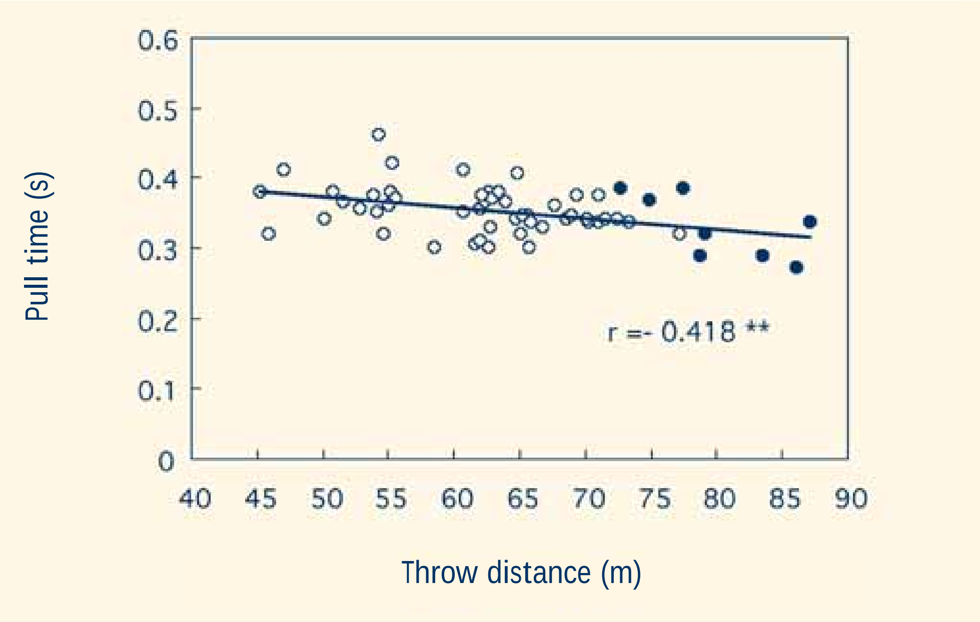

Fig. 8. Relationship between the throw distance and pull time.
**; $p < 0.01$

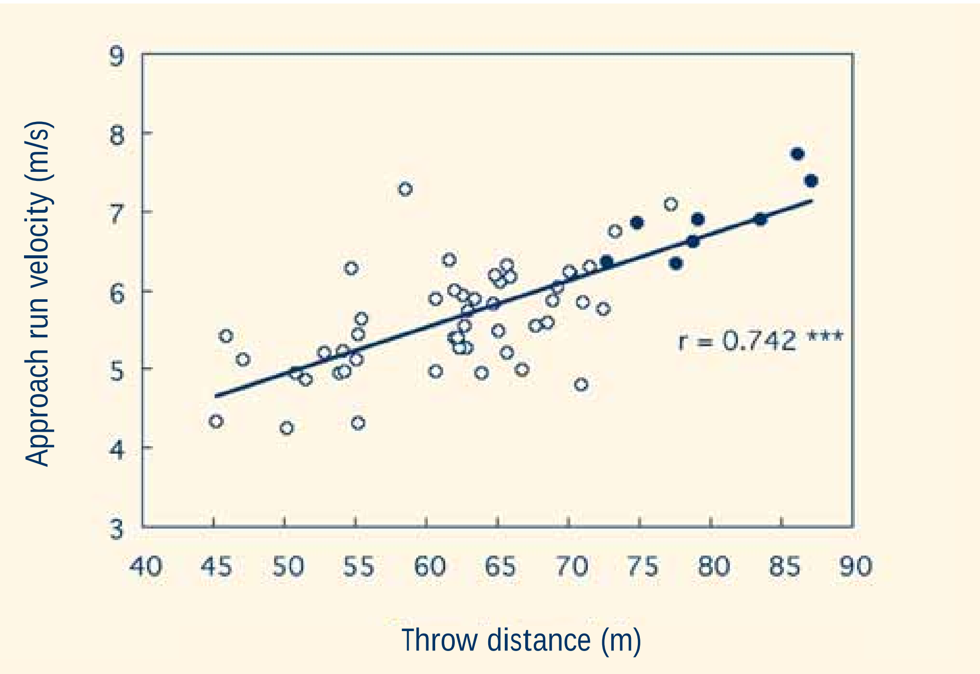

Fig. 9. Relationship between the throw distance and approach run velocity.
***; $p < 0.001$

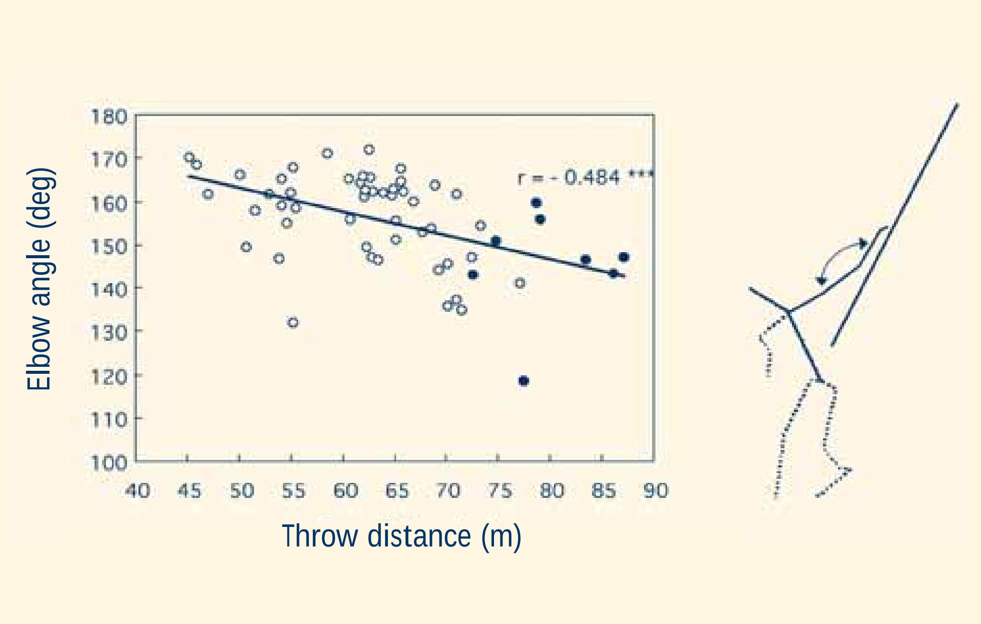

Fig. 10. Relationship between the throw distance and elbow angle.
***; p < 0.001

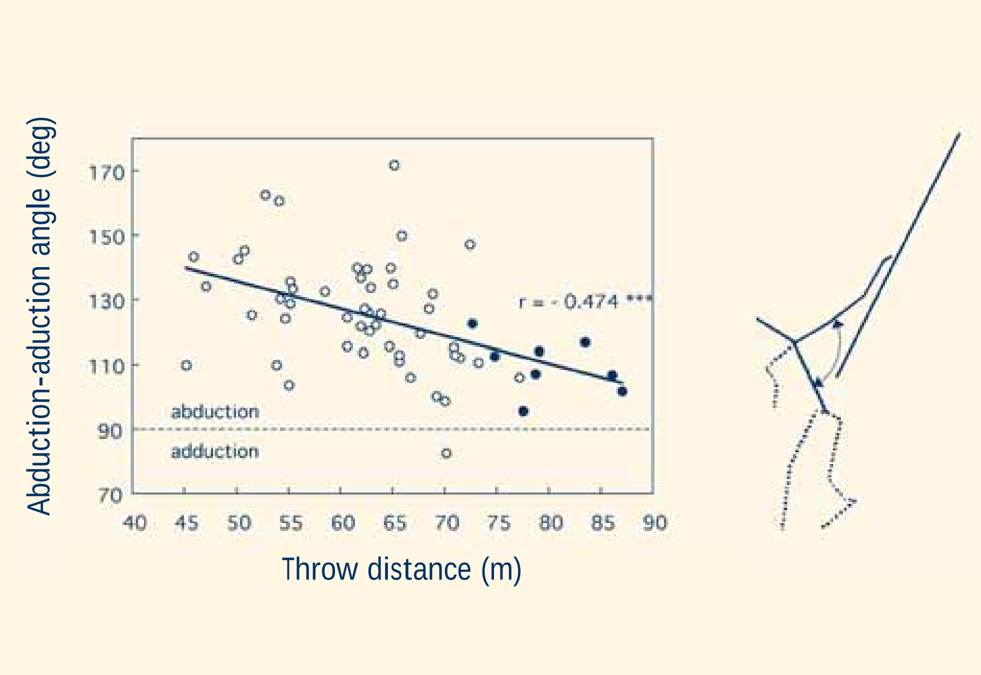

Fig. 11. Relationship between the throw distance and abduction-dduction angle of the shoulder joint.
***; p < 0.001

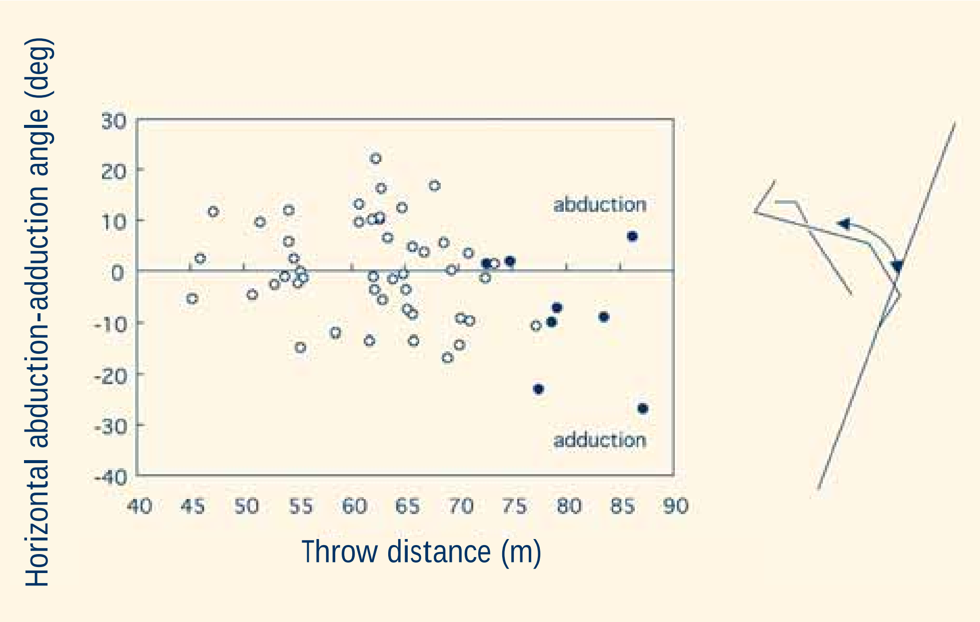

Fig. 12. Relationship between the throw distance and Horizontal abduction-adduction angle of the shoulder joint.

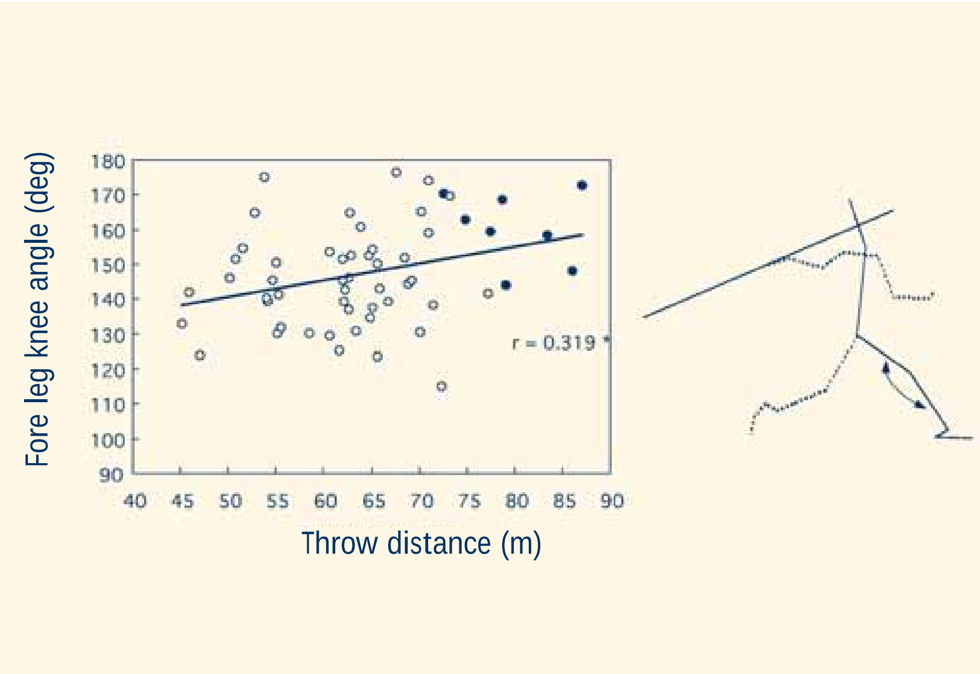

Fig. 13. Relationship between the throw distance and fore leg knee angle.
*; $p < 0.05$

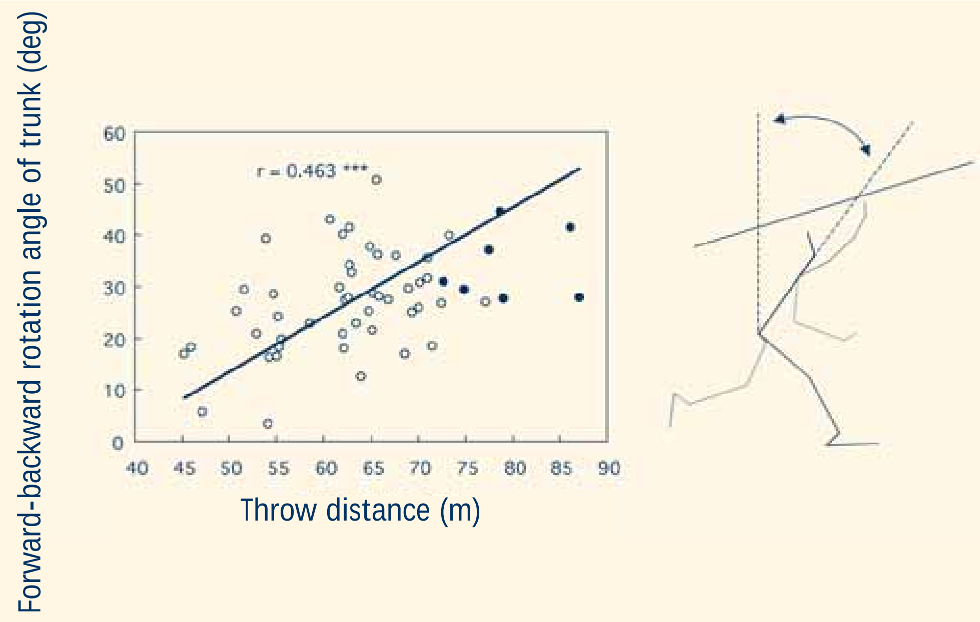

Fig. 14. Relationship between the throw distance and forward-backward rotation angle of trunk.
***; $p < 0.001$

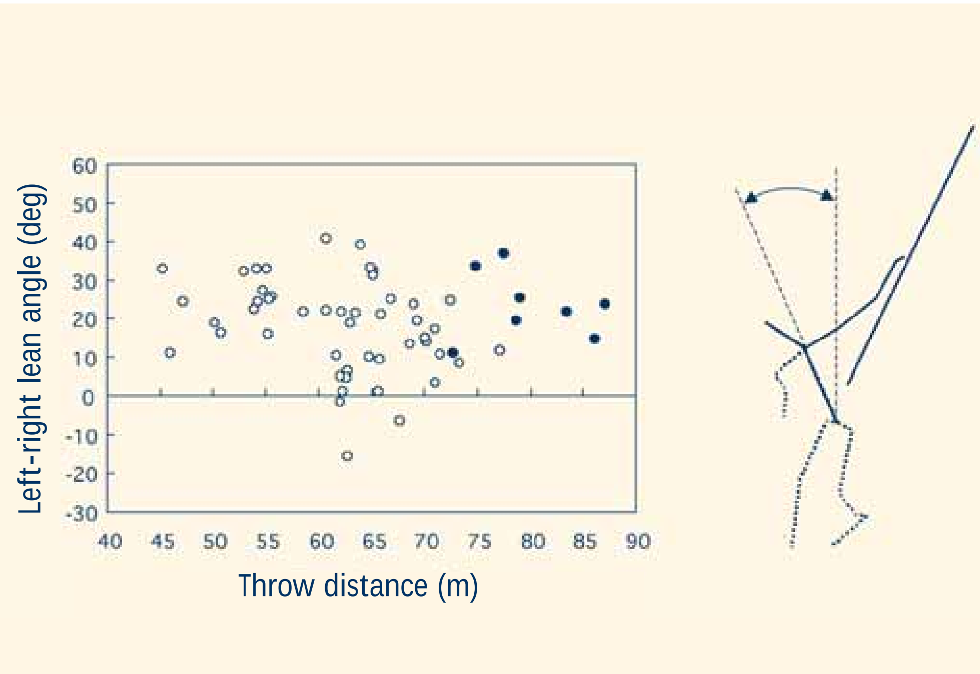

Fig. 15. Relationship between the throw distance and lateral rotation of trunk.
***; $p < 0.001$

REFERENCES

MERO, A.; KOMI, P.V.; KORJUS, T.; NAVARRO, E. ; GREGOR, R.J.: Body segment contributions to javelin throwing during final thrust phases. J. Appl. Biomech.10 (1994): 166-177.

BARTLETT, R.; BEST, R.J.: The biomechanics of javelin throwing: a review. Journal of Sports Sciences. 6 (1988): 1–38.

BARTLETT, R.; MÜLLER, E.; LINDINGER, S.; BRUNNER, F.; MORRISS, C.: Three-dimensional evaluation of the kinematic release parameters for javelin throwers of different skill levels. J. Appl. Biomech. 12 (1996): 58–71.

GREGOR, R.J.; PINK, M.: Biomechanical analysis of a world record javelin throw: A case study. Int. J. Sport Biomech.1 (1985)::73–77.

HUBBARD, M.; ALAWAYS, L.W.: Optimum release conditions for the new rules javelin. Int. J. Sport Biomech. 3 (1987): 207–221.

YOKOI, T.; MCNITTY-GRAY, J. L.: A threshold to determine optimum cut-off frequency in automatic data smoothing using digital filter. Proceedings of the American Society of Biomechanics (14th Annual Meeting) 1990: 209–210.


Goldie Sayers/Photo: © Getty Images