NEW INSIGHTS ON DISCUS THROWING

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An excellent analysis of discus biomechanics that questions some commonly held beliefs. Re-printed with permission from the author.

The last four pages of this paper show a sequence of a typical discus throw. The four rows show views from:

- the right side of the circle
- the back of the circle
- overhead
- a direction roughly perpendicular to the final plane of motion of the discus.

The numbers indicate times, in seconds. (To facilitate the comparison of one thrower with another, the time t=10.00 seconds is arbitrarily assigned in our laboratory to the instant when the left foot makes contact with the ground to start
the final delivery action).

Phases of a Discus Throw

From the end of the backswing until the instant of release, a discus throw can be broken down into five phases:

1. An initial double-support phase (from t=8.86s until t=9.44s in the sequence)
2. A single-support phase on the left foot (t=9.44s - t=9.74s)
3. A non-support phase (t=9.74s = t=9.84s)
4. A second single support phase, on the right foot (t=9.84s - 1=10.00s)
5. The delivery phase (t=10.00s - t=10.19s), which occurs mainly in double-support, but often ends in single-support or in non-support due to loss of ground contact by one or both feet prior to the release of the discus.

Forces, Linear Momentum and Rotary Momentum

In the course of a throw, the feet make forces on the ground. By reaction, the ground makes equal and opposite forces on the feet. These reaction forces give **linear momentum** to the combined thrower-plus-discus system. **Forward linear momentum** is generated in the early stages of the throw. It makes the system translate horizontally across the throwing circle.

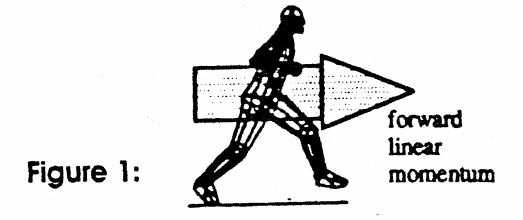


Figure 1:

Upward linear momentum is added during the delivery phase

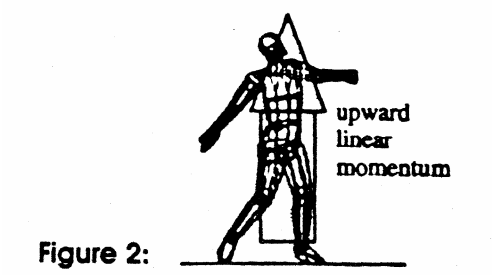


Figure 2:

The linear momentum makes the thrower-plus-discus throwing platform translate forward and upward at the instant of release. That way, it contributes to increase the horizontal and vertical speeds of the discus and, therefore, the distance of the throw.

The ground reaction forces also give **rotary momentum** to the thrower-plus-discus system. There is rotary momentum in two independent directions:

1. "Z" rotary momentum, about the vertical axis, visible as a counterclockwise rotation in a view from Figure 3.

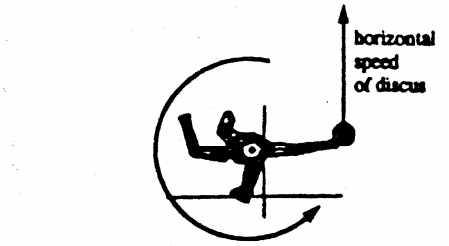


Figure 3 Z rotary momentum about vertical axis

2. "Y" rotary momentum, about a horizontal axis aligned with the midline of the throwing sector. Visible as a counterclockwise rotation in a view from the back of the circle, Figure 4.

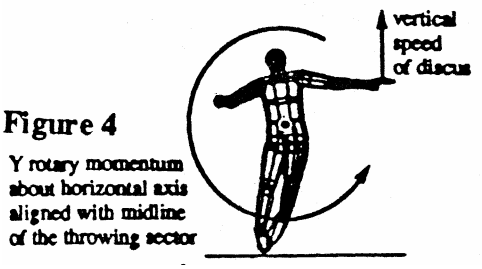


Figure 4
Y rotary momentum about horizontal axis aligned with midline of the throwing sector

A transfer of "Z" rotary momentum from the thrower to the discus imparts **horizontal speed** to the discus (Figure 3); it also tends to slow down the thrower's counterclockwise

rotation in the view from overhead. A transfer of “Y” rotary momentum from the thrower to the discus imparts **vertical speed** to the discus (Figure 4); it also tends to slow down the thrower’s counter-clockwise rotation in the view from the back of the circle.

Previous Ideas

It is generally believed that the rotation of the thrower-plus-discus system about a vertical axis can only be generated while both feet are in contact with the ground (Housden, 1959) through a “pull-push” mechanism, such as the one shown in Figure 5. There are two such periods in every throw:

1. Double-support phase at the back of the circle

2. The double-support phase during the final delivery.

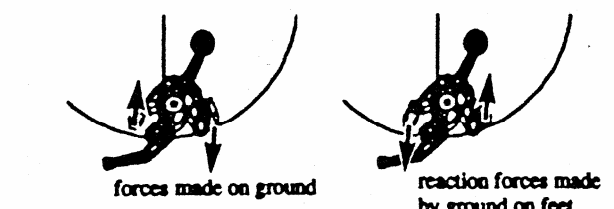


Figure 5

Until now, due to the lack of research into this question, the roles of these two double-support phases have not been clear. However, much of the coaching literature has tended to stress the importance of the delivery phase at the expense of the earlier part of the throw, which is often seen as little more than a mere preparation for the start of the all-important delivery phase (i.e. see Schmolinsky, 1978; Scholes, 1978: Lenz. 1985).

According to most authors, the emphasis should be put mainly on the achievement of a good position of the body at the instant the left foot is planted, and on the execution of a very dynamic delivery phase. Only limited importance is given to the execution of dynamic motions in the part of the throw that precedes the delivery phase. In other words, according to most authors, it would seem that a good technique would constitute if a thrower can:

- Manage to move at a slow-to-moderate pace in the part of the throw prior to the delivery phase

- Reach the start of the delivery phase in a good position, and then

- Execute a very dynamic delivery.

However, the results of a research project at our laboratory indicate that this is not the case: discus throwers have to be very dynamic in the parts of the throw that precede the delivery phase.

Generation of Discus Speed

A three-dimensional biomechanical analysis of three male discus throwers showed that:

- The forward linear momentum of the thrower plus-discus system contributed 7% of the horizontal speed of the discus at release,

- while the “Z” rotary momentum contributed the remaining 93%.

- The upward linear momentum contributed 12% of the vertical speed of the discus at release,

- while the Y rotary momentum contributed the remaining 88%.

In other words, the forward linear momentum and upward linear momentum of the thrower-plus discus system made minor contributions to the speed of the discus: the main contributions came from the “Z” rotary momentum and the “Y” rotary momentum.

Horizontal Speed. Rotary momentum about the vertical axis:

- “Z” rotary momentum, or counterclockwise rotary momentum in a view from overhead (see Figure 3) was obtained from the ground by the thrower-plus-discus system during the first double-support phase t=8.86s - t=9.44s) in the sequence.

- It was generated by pull-push forces (Figure 5): during the early part of the first single- support phase (t=9.44s – 9.60 s).

- It was generated by an off-center ground reaction force that passed somewhat to the right of the center of mass (c.m.) of the thrower-plus-discus system (Figure 6).

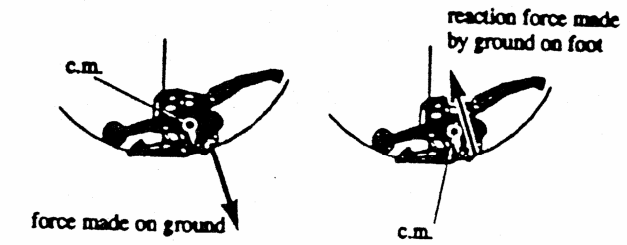


Figure 6

Note: The forces shown in the drawings are only approximations: a study using force plates, rather than film analysis, would be necessary for a more exact measurement of the values of these forces. The rotary momentum obtained was ‘stored’ primarily in the thrower; at this stage of the throw, the discus was given only a small share of the total rotary momentum of the thrower-plus-discus system.

The most remarkable finding of the study was that the thrower-plus-discus system did not contain any further “Z” rotary momentum after the first single-support phase:

- **During the delivery phase, there was no gain in the “Z” rotary momentum of the thrower-plus-discus system!**

Presumably, the thrower was rotating so quickly about the vertical axis by then, that the feet found it impossible to make horizontal pull-push forces on the ground. What did occur during the delivery phase (t=10.00s - t=10.19s in the sequence) was a tremendous **transfer of rotary momentum** within the thrower-plus-discus system:

- a transfer of rotary momentum from the thrower to the discus.

This produced a very large increase in the **horizontal speed** of the discus that has been observed previously in this phase of the throw by other researchers. It occurred in conjunction with a marked slowing down of the counterclockwise rotation of the thrower. This important transfer of rotary momentum was due, in part, to an inertial mechanism, and, in part, to the muscular efforts of the thrower, but it had nothing to do with any interaction with the ground during the delivery phase of the throw.

Vertical Speed. The rotary momentum about a horizontal axis aligned with the midline of the throwing sector ("Y" rotary momentum, or counter-clockwise rotary momentum) in a view from the back of the circle (see Figure 4) is important for the generation of the vertical speed of the discus. During the second half of the second single-support phase and the first half of the delivery phase (t=9.88s - t=10.08s in the sequence), the thrower-plus-discus system received from the ground a force that passed to the right of the center of mass (Figure 7). This force was exerted through the right foot during the single-support phase and possibly also during the early delivery phase. Since the force was off-center (in other words, since it did not point directly through the center of mass), it gave the thrower counter-clockwise rotary momentum in the view from the back of the circle.

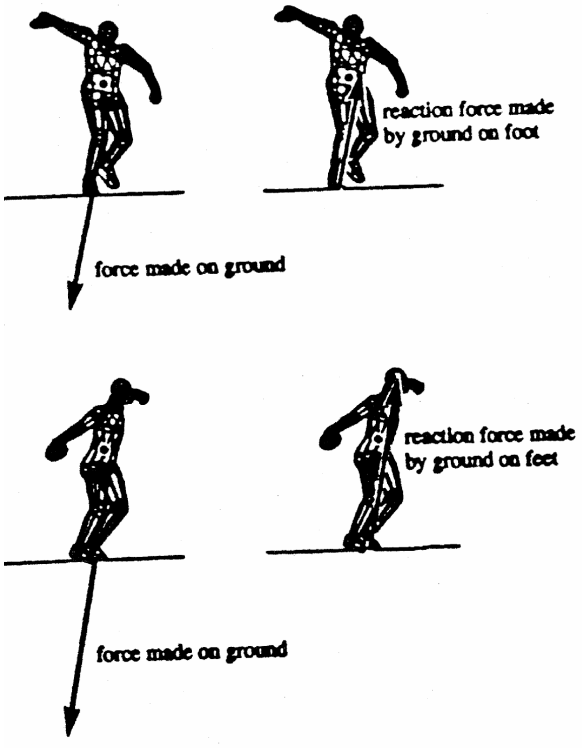


Figure 7

In the second half of the delivery phase (t=10.10s - t=10.19s), part of the counter-clockwise rotary momentum that had been generated during the second half of the second single-support phase and first half of the delivery phase was transferred from the thrower to the discus. This transfer of rotary momentum produced most of the **vertical speed** of the discus.

In similar fashion to what occurred with the "Z" component of rotary momentum, there was no net gain of "Y" rotary momentum for the thrower-plus-discus system during the transfer

of “Y” rotary momentum from the thrower to the discus. In fact, while “Y” rotary momentum was being transferred from the thrower to the discus, the thrower-plus-discus system received from the ground a force that passed to the **left** of the center of mass (Figure 8). Since the force was off-center and passed to the left of the c.m., it took away part of the counterclockwise rotary momentum that the thrower-plus-discus system had accumulated previously. Therefore, the “Y” rotary momentum that the discus obtained from the thrower in the second half of the delivery phase did not come from interaction with the ground at that same time, because at that time, the ground was actually contributing to reduce the counter-clockwise “Y” rotary momentum of the system.

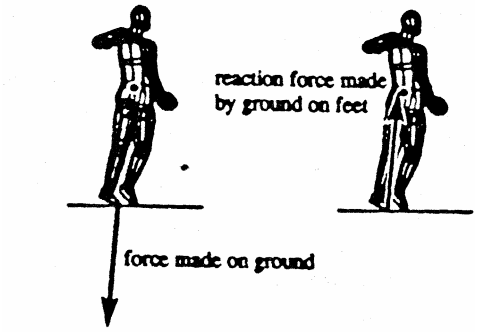
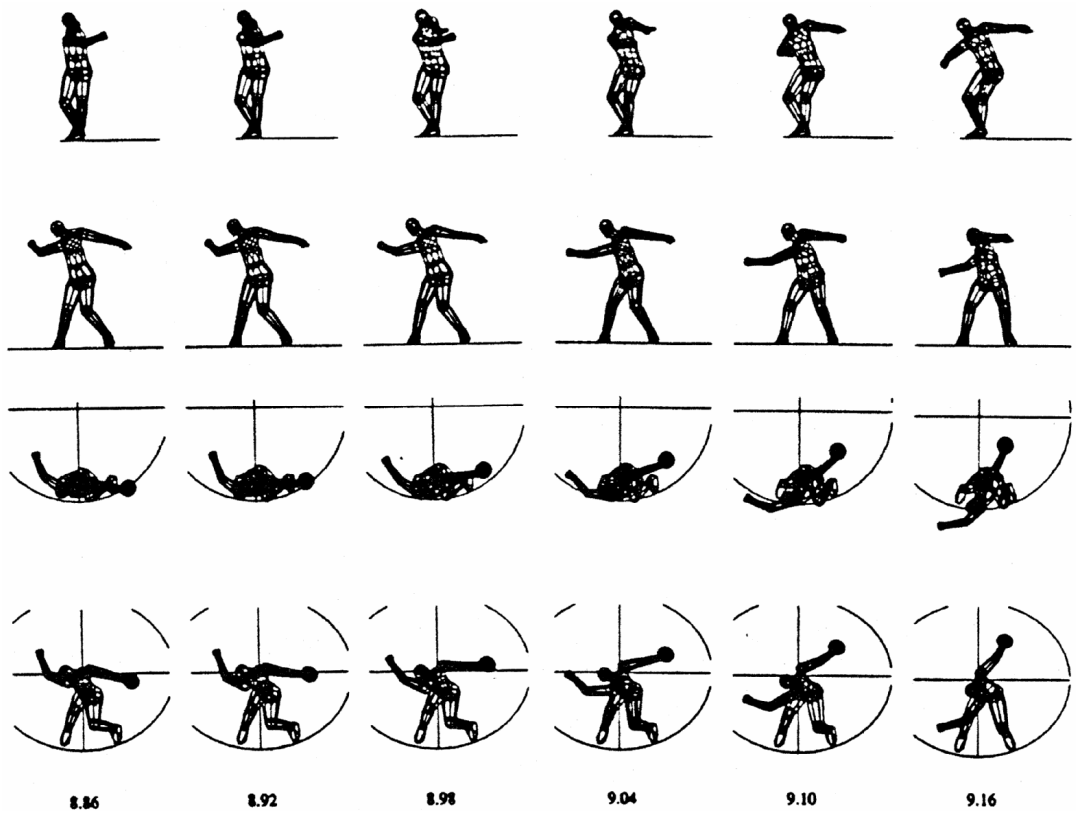
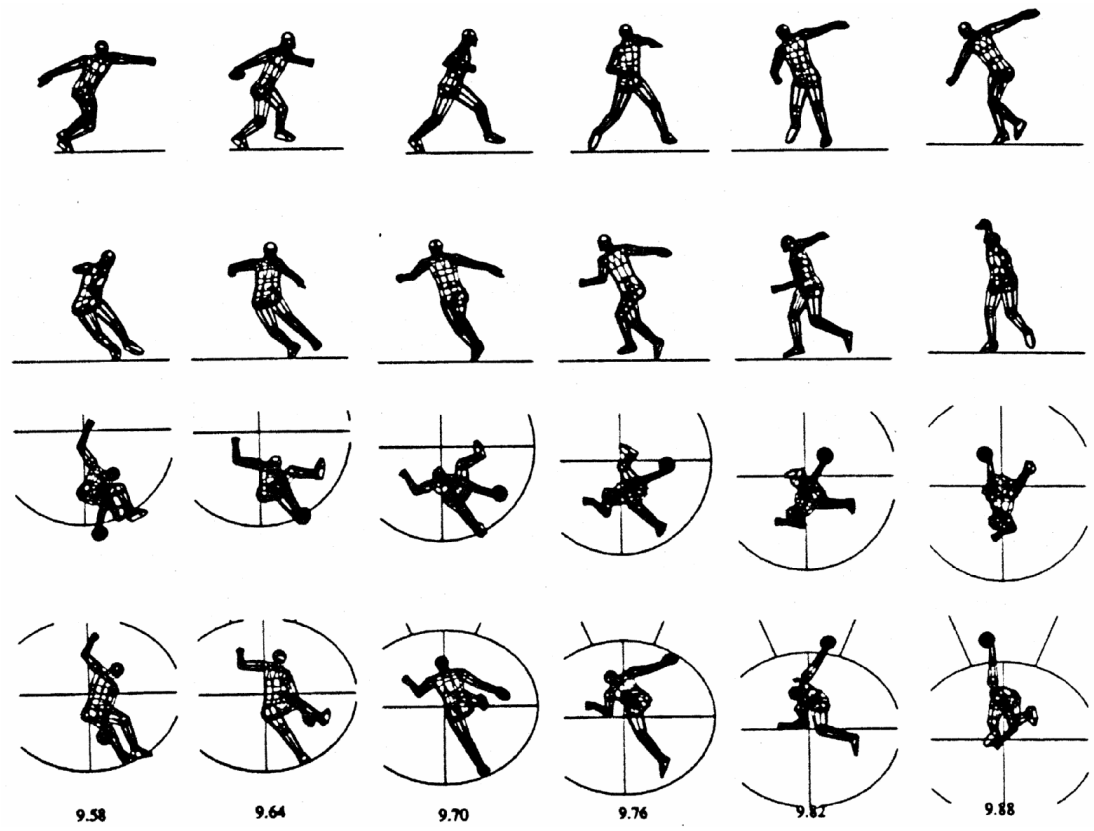


Figure 8

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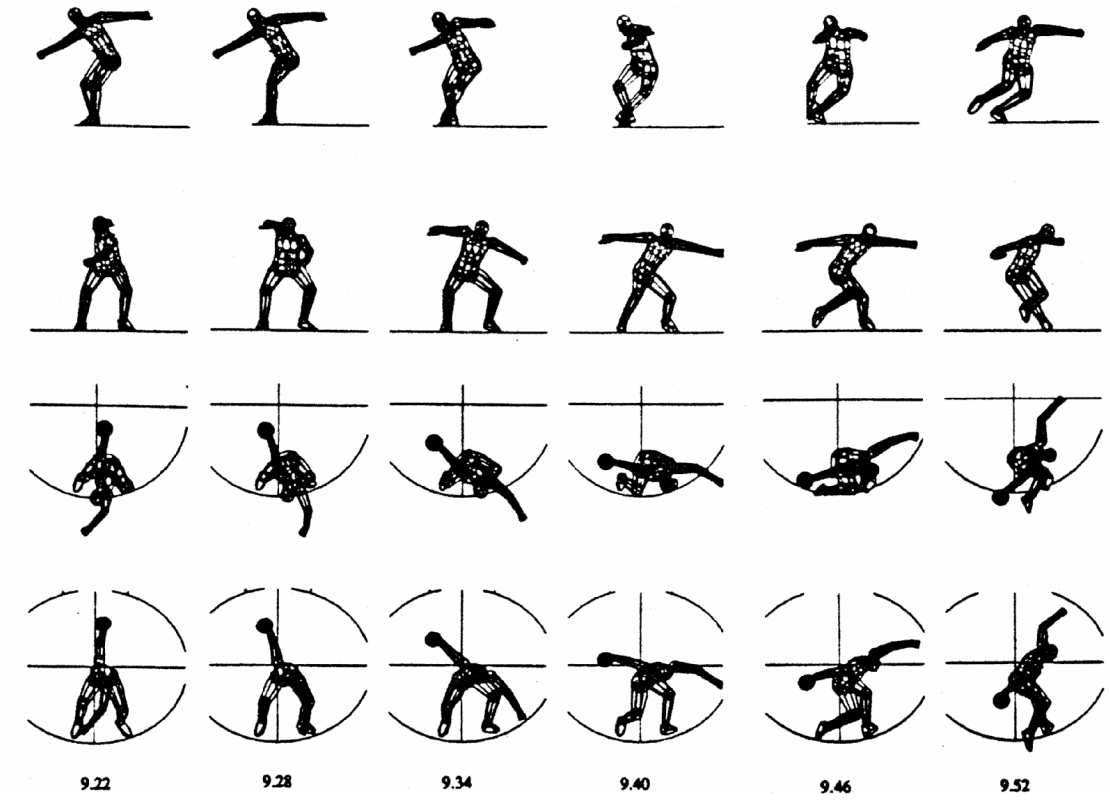
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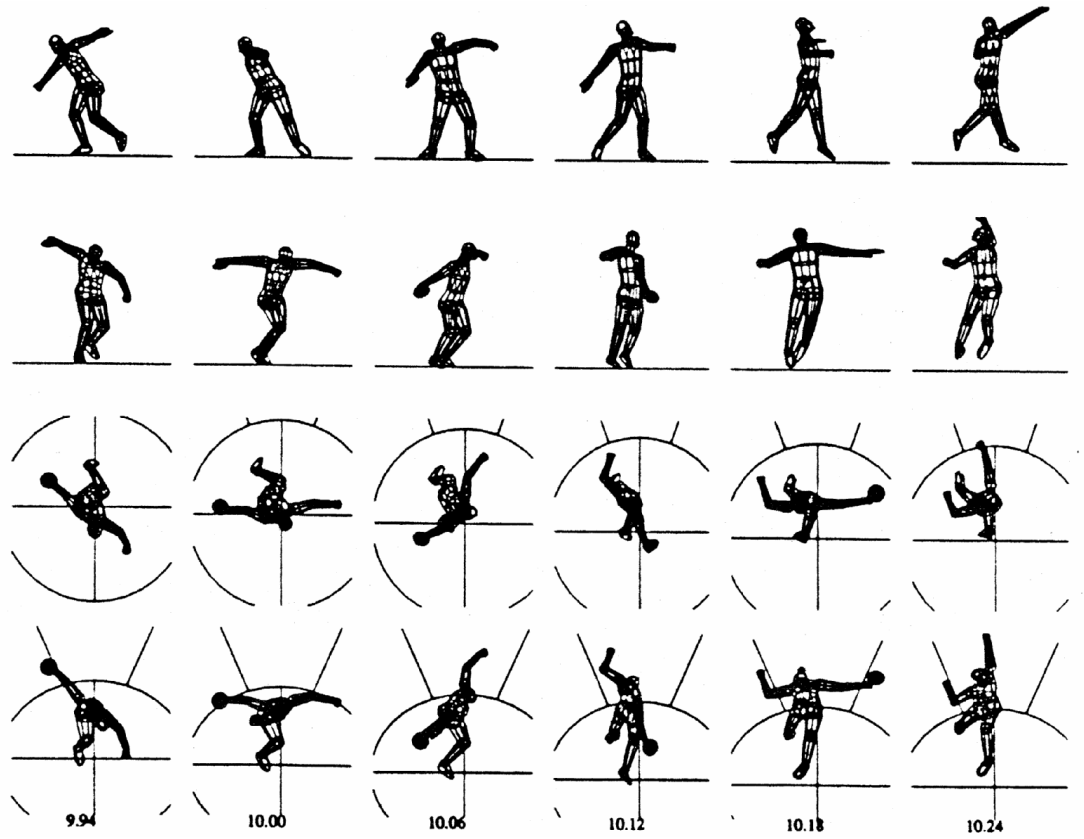

Summary

"Z" rotary momentum (an essential requirement for the generation of the horizontal speed of the discus) is passed on to the discus during the entire delivery phase, and "Y" rotary momentum (an essential requirement for the generation of the vertical speed of the discus) is passed on to the discus during the second half of the delivery phase. However, both are obtained from the ground earlier on:

- The "Z" rotary momentum, in the first double-support phase and the first single-support phase
- The "Y" rotary momentum, in the second half of the second single-support phase and the first half of the delivery phase.

The rotary momentum is stored primarily in the body of the thrower (where it expresses itself as a rotation of the body) before being passed on to the discus later on in the delivery phase.

(Credit must be given to Ecker (1976), who, without the benefit of research data, reached many of the same conclusions as this paper. The only shortcoming of Ecker's interpretation was that he did not make a clear distinction between the rotary momentum of the thrower-plus-discus system and the rotary momentum of the discus alone.)

Practical implications

The first double-support, first single-support and second single-support phases are much more important than has generally been acknowledged up to now. This is when ground

reaction forces give the body most of the rotary momentum that will be passed on to the discus during the delivery phase. If the thrower did not elicit these forces from the ground prior to the delivery phase, there would not be much rotary momentum available to pass on to the discus in the delivery phase and, therefore, it would be difficult to impart a large speed to the discus.

Consequently, an experienced thrower with a good technique will not only reach the start of the delivery phase in a good position, and execute a very dynamic delivery: The thrower will also be **very dynamic in the early stages of the throw**. This means that the athlete will exert on the ground:

- Large horizontal “pull-push” forces in the first double-support phase (Figure 5). and
- A large horizontal force backward with the left foot during the single-support phase that follows (Figure 6).

Greater activeness in the early stages of the throw does not mean that the discus has to be accelerated early; on the contrary, the conventional wisdom that the discus should remain far behind the trunk until the start of the delivery phase is still valid. The discus then receives a large amount of rotary momentum from the body during the delivery phase, and finally catches up with the trunk at the instant of release.

Important Caution: *In the early stages of the throw, a **beginner** should emphasize **control, rather than activeness**. Only after the thrower has gained considerable experience, should there be a gradual transition to a technique that emphasizes the very dynamic motions that are necessary in the early stages of the throw for the achievement of World-level results.*

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