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Selected Delivery Dynamics in Discus Throwing

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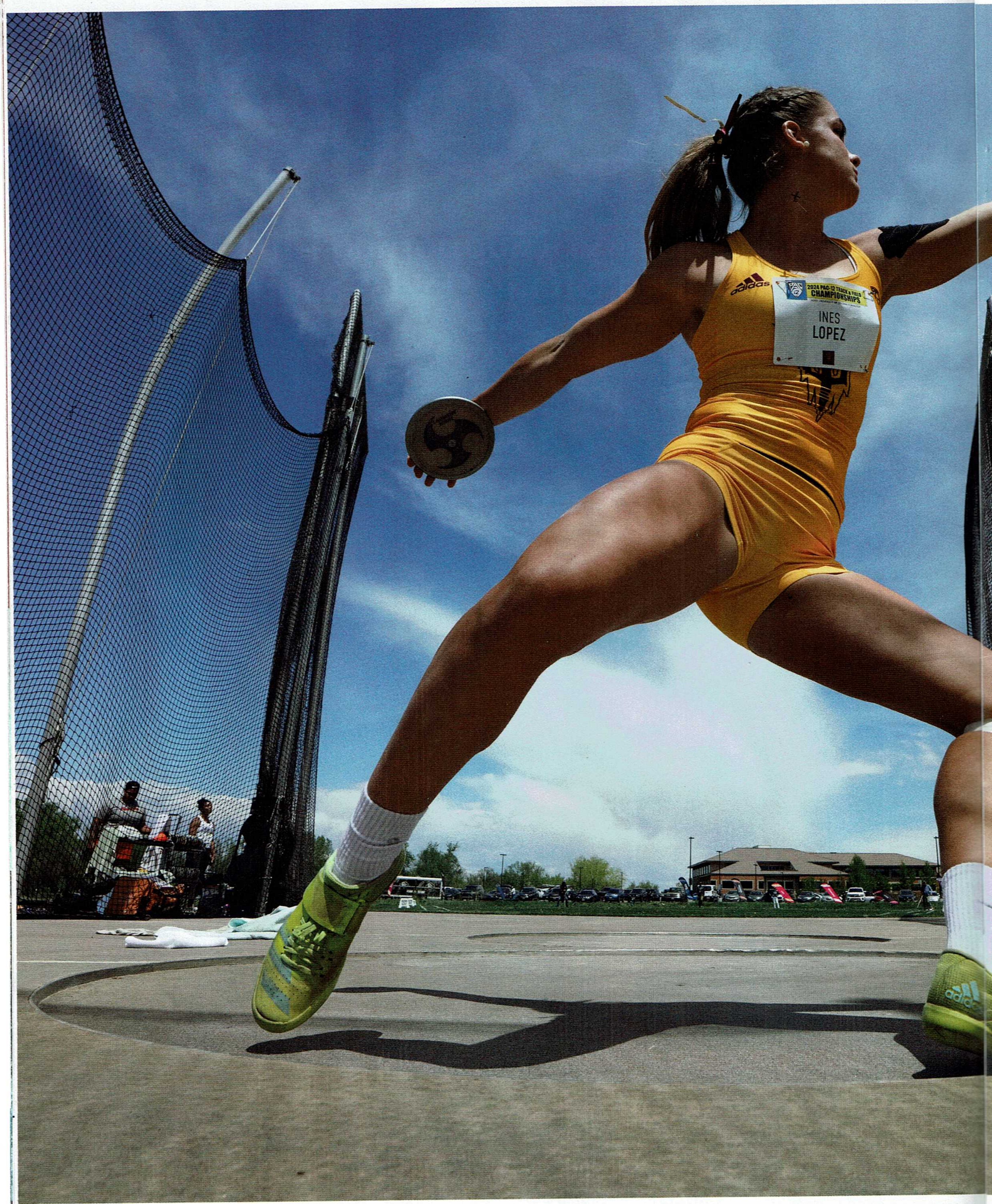
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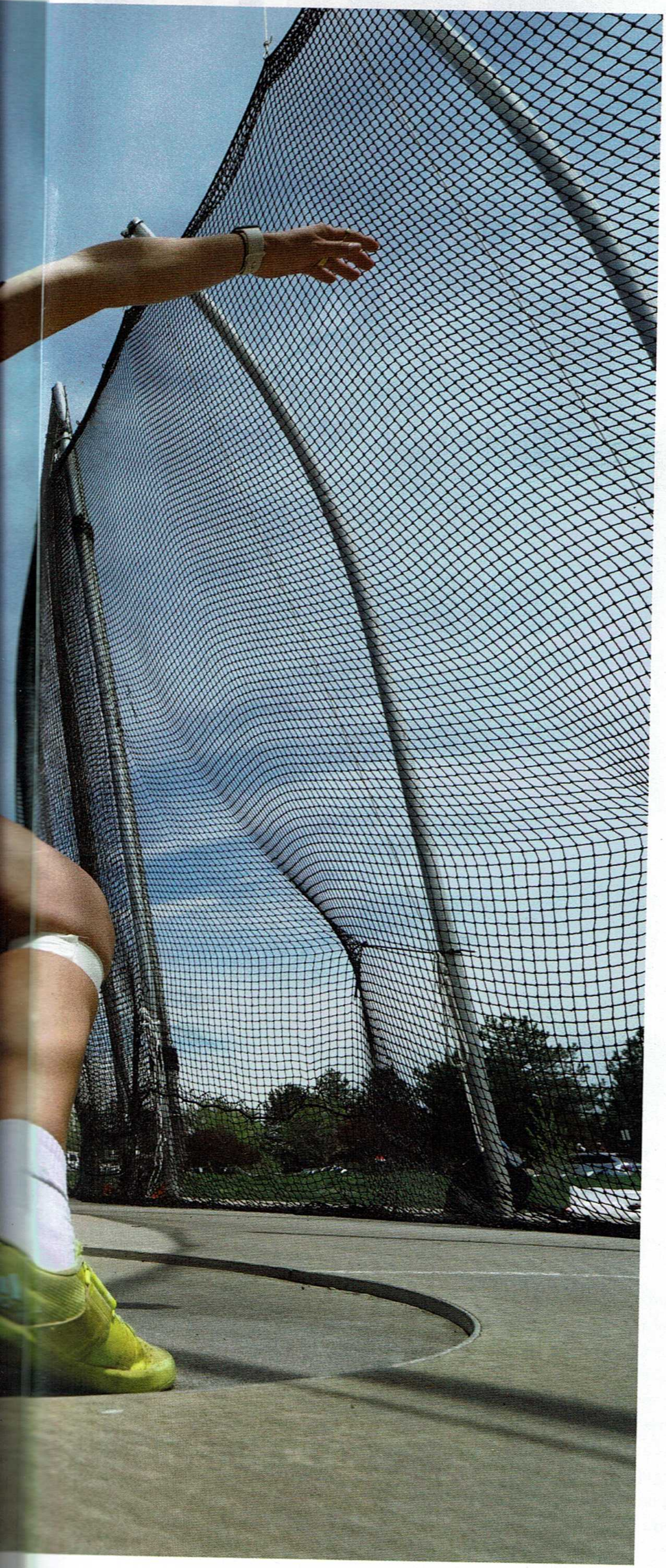

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Theory and Practice

Selected Delivery Dynamics in Discus Throwing

In discus throwing, the period of time between the landing of the left foot in the front of the ring and the actual release of the discus, is called the delivery phase. During that phase all discus throwers are in double support (both feet on the ground) for the majority of its duration. However, at the moment the discus is released, there are differences among throwers in that some maintain contact with the ground at release whereas others have lost contact with the ground at that moment, with both feet. everal years ago coaches, particularly Europeans, would advocate the maintenance of both feet on the ground at release, (whether a no reversing, or a quasi reversing or a full reversing of the feet technique was employed), an idea that made sense from a biomechanical point of view and was widely adopted. In fact, those days almost all women discus throwers would exclusively employ the grounded, double support, technique of releasing the discus. In the subsequent years, work carried by Dapena & Anderst (1997), has shed some light on what may be happening during grounded (one or both feet on the ground), or airborne (both feet off the ground) release of the discus. A discussion of the major concepts involved during that exact phase in discus throwing and whether one or the other method is more advantageous, is presented below. Since, at the moment of the discus release, its velocity is of paramount importance, the examination of velocity itself is central both in the horizontal and the vertical directions.

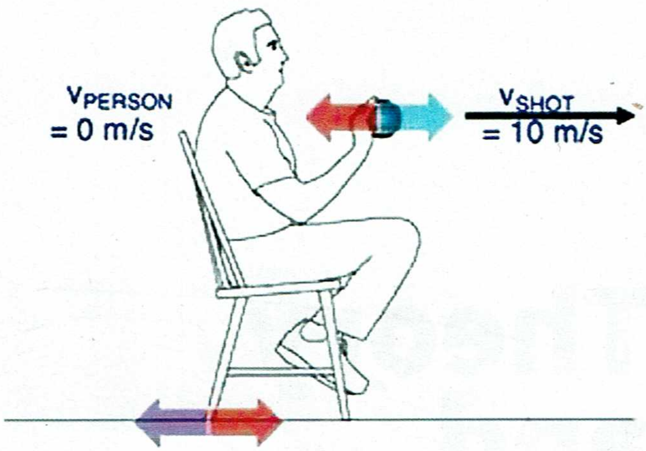

FIGURE 1. RUDIMENTAL FORCES AND HYPOTHETICAL VELOCITIES INVOLVED IN A SEATED FORWARD PUSHING OF THE SHOT, (ADAPTED FROM DAPENA, 2024).

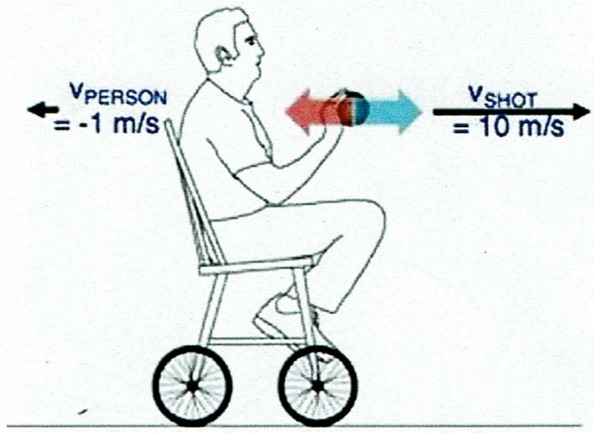

FIGURE 2. RUDIMENTAL FORCES AND HYPOTHETICAL VELOCITIES INVOLVED IN A SEATED (ON WHEELS) FORWARD PUSHING OF THE SHOT (ADAPTED FROM DAPENA, 2024).

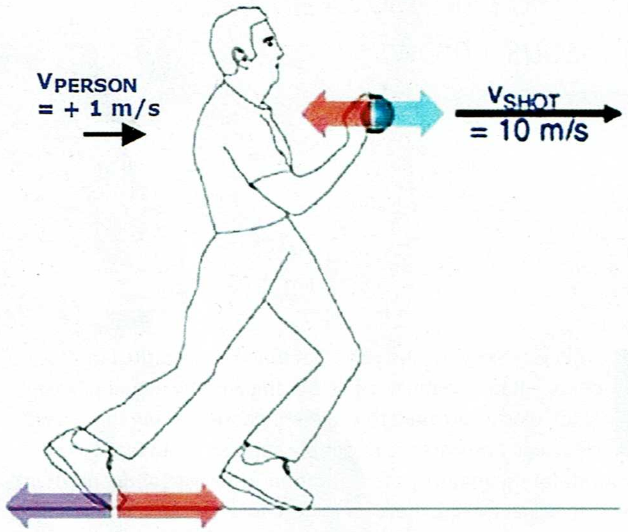

FIGURE 3. RUDIMENTAL FORCES AND HYPOTHETICAL VELOCITIES INVOLVED IN AN UPRIGHT FORWARD PUSHING OF THE SHOT (ADAPTED FROM DAPENA, 2024).

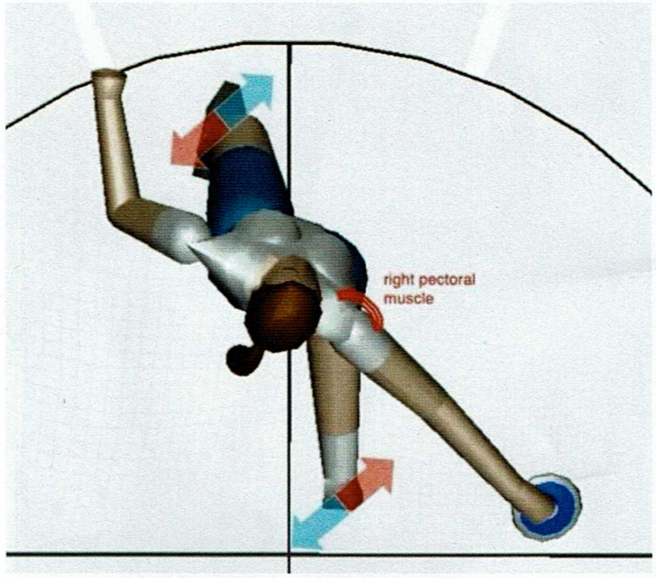

FIGURE 4. PUSH-PULL FORCES EXERTED BY THE FEET ON THE GROUND DURING DELIVERY (ADAPTED FROM DAPENA, 2024).

MECHANICAL BASIS FOR THE GROUNDED DELIVERY

1. Linear movement, horizontal velocity

One can follow different kinds of logic to assess the advantages or disadvantages of being off or on the ground during discus release, but a simple example using translational (linear) movement is as shown in figure 1. Here we have a person sitting on a chair while attempting to push a shot straight out and forward. He is exerting a force on the shot (blue arrow) and the reaction to that force is in the opposite direction (red arrow) and is of the same magnitude. Since the thrower is connected to the chair, together they act as one system. Therefore, as the thrower pushes the shot forward, the shot pushes the system backwards so the legs of the chair push backwards (purple arrow) and the reaction to that force is again an opposite force (red arrow) of the same magnitude. Since the two reaction forces (the two red arrows) are equal and in opposite directions, they add to zero and the system indeed remains steady and with no velocity. In these early stages of the attempt the shot may have reached a velocity relative to the ground, of say 10 m/s., with the velocity relative to the person's shoulder, also at 10 m/sec.

A similar situation is shown in figure 2, with the chair, however, being supported on wheels. In this case, there will not be a reaction force from the chair and the chair+thrower system will move backwards at a velocity that will depend on the mass of the person and the weight of the shot. For practical purposes we will assume that the backwards speed is at 1 m/s. Under those conditions, the shot's velocity relative to the ground will again be 10m/s., however, the shot's velocity relative to the shoulder of the thrower will be 10+1=11 m/sec. Since higher velocities should require faster contractions of the muscles involved in the throw, and since muscles can exert larger forces at slower speeds of contraction (Hill, 1922), in this case, a higher relative speed between the shot and the thrower means that the thrower under those conditions can exert less force, in the ensuing effort to fully extend the arm, as compared to the first case in figure 1. So the set up in figure 1 (net zero velocity of the chair+thrower system) is more conducive to higher force generation.

Another potential set up is shown in figure 3. Here the thrower is upright and in contact with the ground. The action - reaction forces on his hand are the same as in the other cases as is the velocity of the shot at that exact time. However, here, the thrower can choose to actually use his leg muscles and exert a large force on the ground (long purple arrow) which will produce the reaction force (long red arrow). Obviously, the reaction force exerted by the shot on the hand, is smaller than that on the feet. At the time then, the shot is reaching the 10 m/s., velocity, the body of the thrower is also moving forward at, say, 1 m/s. In this case, the velocity of the shot relative to the ground will again be 10 m/s., but the velocity of the shot relative to the shoulder of the thrower will be, 10-1= 9 m/s. Therefore, here, this lower relative speed of the shot means that the thrower will be able to exert an even larger force on the shot. Comparatively then, the set up in figure 3 is the best (better potential for force exertion), followed by that in figure 1, while the one in figure 2 is not recommended.

From all described above, mechanically speaking, it is to the advantage of the thrower to keep both feet on the ground during the delivery phase of the projectile. Jumping up during release (losing contact with the ground) will be similar to the set up in figure 2, where there is a backwards acceleration of the thrower's body resulting in less potential to exert maximum force.

2. Rotational movement, horizontal velocity

In discus throwing, during the delivery

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TABLE 1. PERVENTAGE OF TOTAL ANGULAR MOMENTUM, ABOUT THE VERTICAL AXIS, PRODUCED IN THE DELIVERY PHASE.

	RELEASE IN THE AIR	RELEASE IN GROUND SUPPORT
MEN n = 24	10.7 ± 7.0 n = 19	3.8 ± 10.9 n = 5
WOMEN n = 17	14.7 ± 5.7 n = 9	9.0 ± 6.5 n = 8

TABLE 2. AVERAGE VERTICAL VELOCITY OF THE SYSTEM'S CENTER OF MASS, IN THE LAST 1/4 TURN.

	RELEASE IN THE AIR	RELEASE IN GROUND SUPPORT
MEN n = 24	1.5 ± 0.2 n = 19	1.1 ± 0.2 n = 5
WOMEN n = 17	1.3 ± 0.2 n = 9	0.9 ± 0.2 n = 8

phase (figure 4), there is also a theoretical mechanical advantage in maintaining contact with the ground throughout the delivery phase for the same reasons described earlier, namely, the grounded release allows the muscles to be in slower contractions, resulting in higher force production, which is associated with obtaining a greater amount of angular momentum from the ground. Figure 4, shows the ground forces exerted by the thrower on the ground (blue arrows) which result in the reaction forces (red arrows). If the thrower were to jump up and lose contact with the ground the forces depicted in blue will be absent (as will the reaction forces in red) and the generation of angular momentum will be, theoretically, compromised.

The aforementioned reasons are the foundation behind the logic to conclude that being in double support throughout the delivery phase is the prudent way to release the discus.

ANGULAR MOMENTUM CONSIDERATIONS

To better quantify the size of the angular momentum and its significance during the delivery phase, first, we are going to hypothesize that by remaining in double support during the whole delivery phase, a thrower can produce 20% more angular momentum than if throwing airborne. Although empirically this seems to be an optimistic percentage, it is nevertheless a significant improvement and will aid in producing more horizontal speed for the discus. It needs to be pointed out here that, around 90% of the angular momentum about the vertical axis (horizontal velocity of the discus) is generated at the back of the ring and only around 10% is generated during the delivery phase (for more see Maheras, 2022). Therefore, the hypothetical 20% improvement mentioned above does not mean that the advantage will be a comparative 20% increase in the total angular momentum. Rather, it would be a 20% increase in the small, 10%, of angular momentum that is produced in the delivery phase. Twenty percent of 10% would be only 2% of the total angular momentum produced during a discus throw. So assuming that there is a practical advantage of the grounded release method, that would be minimal. However, even 2% is better than none, so, so far, it seems that staying in the ground is better than losing contact during the discus release.

Many coaches have found it logical to assume that the majority of angular momentum was generated at the front of the ring during the all-in, explosive delivery phase. This way all attention was focused to that phase and emphasis was given to the release method (grounded release) as the method that will produce the bigger advantage.

FROM THEORY TO PRACTICE

Table 1, shows the angular momentum values during the delivery phase, observed by male or female throwers, as a percentage of the total angular momentum produced during a discus throw (Dapena & Anderst, 1997). Those values show, that throwers who were airborne at discus release were able to generate higher percentage values of the total angular momentum generated, during the delivery phase as compared to those who maintained contact with the ground. This is an unexpected result as all theoretical evidence had led us to believe that no matter how small the advantage, indeed there should be an advantage when employing the grounded method of releasing the discus.

LINEAR MOVEMENT, VERTICAL VELOCITY

An attempt to try to explain the observed discrepancy could, in addition to the horizontal, examine the production of linear vertical velocity also. For that, the average vertical velocity of the center of mass during the last quarter turn, roughly from the low point of the discus until release, will be considered (Dapena & Anderst, 1997). Table 2 shows the vertical velocity of the center of mass, for both genders, during the mentioned period. It shows that in all cases the vertical velocity for the grounded release method is significantly lower compared to that during the airborne method.

The thinking on the part of the grounded release method may be, that during the delivery of the discus although the vertical velocity of the center of mass (vertical velocity of the discus) may be lower in the grounded method, the opportunity to produce large angular momentum about the vertical axis (horizontal velocity of the discus) is greater and that this advantage, may give the grounded method a better overall result. However, as it was discussed earlier, this is not the case. The grounded release method does not seem to produce neither larger amounts of angular momentum, nor does it produce higher values of vertical velocity during the delivery phase.

To explain the apparent failure of the grounded throwers to produce more angular momentum around the vertical axis at release, Dapena (2024), speculated that during the delivery phase the thrower pushes directly downwards against the ground, and at the same time he is also making push-pull forces that are exerted by the feet on the ground during that phase (figure 4). In the case of the grounded method, the thrower, to avoid becoming airborne, may inhibit the production of large forces in the vertical direction, and incidentally and unwillingly he may also inhibit the production of push-pull forces the ones that are mostly responsible for the production of the generation of angular momentum about the vertical axis and the horizontal velocity of the discus.

SUMMARY

Releasing the discus in double support as compared to being airborne has only a small effect on the result of the throw. In the vertical direction, releasing the discus while in the air produces more vertical velocity for the thrower, helping in the production of more vertical velocity for the discus. As for the horizontal velocity, theoretically, being on the ground during release should allow for the generation of more angular momentum about the vertical axis and eventually the production of more horizontal velocity for the discus. In practice though, the opposite is true. Releasing the discus while airborne, produces more angular momentum about the vertical axis and higher horizontal velocity for the discus. According to the presented data, releasing the discus with the feet on the ground is a bit worse than releasing the discus while airborne.

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