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for Track & Field and Cross Country

VOLUME 9, NUMBER 4 MAY 2016



LONG DISTANCE

BASIC AERODYNAMICS AND FLIGHT CHARACTERISTICS IN DISCUS THROWING

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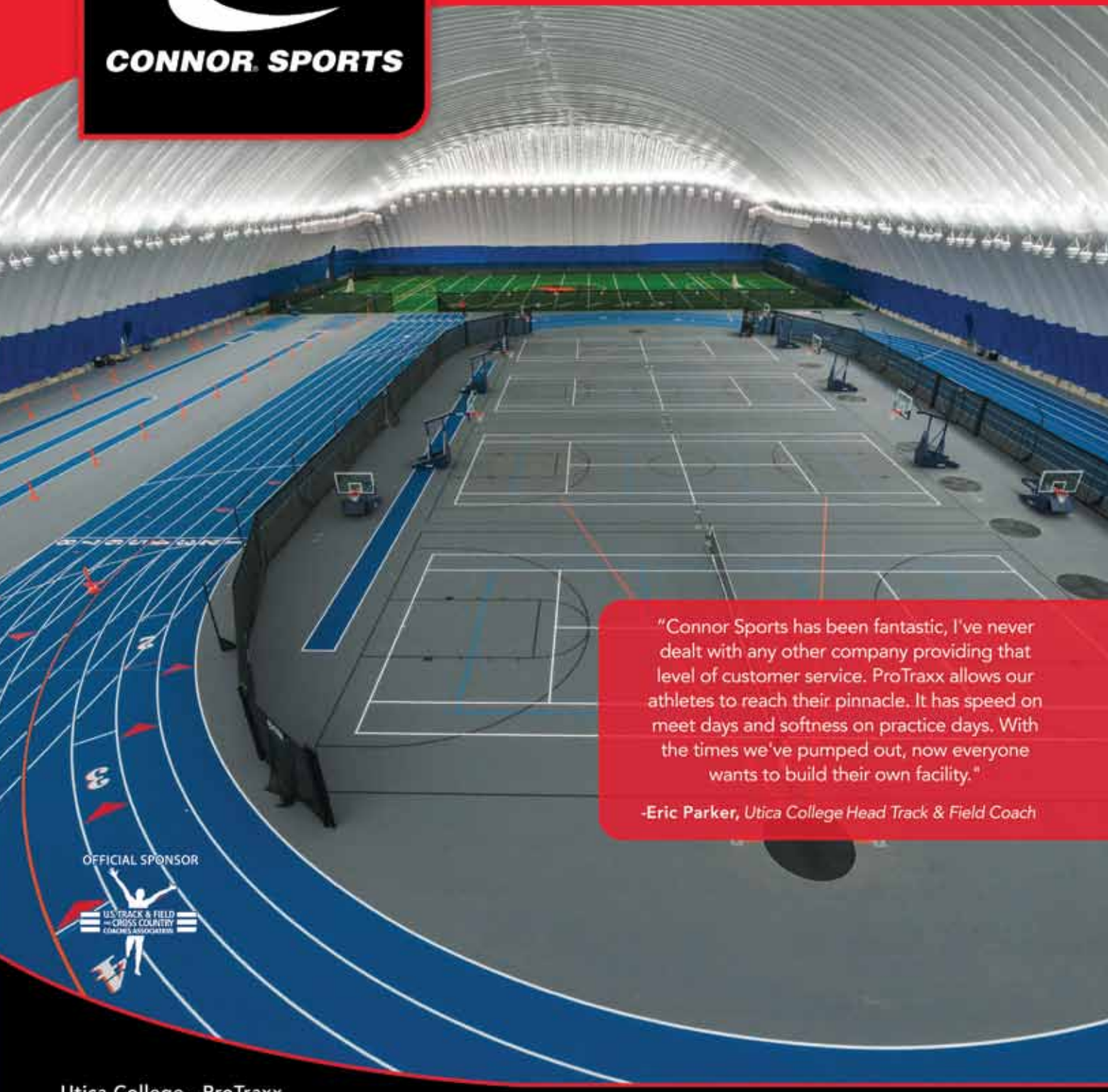
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A LETTER FROM THE PRESIDENT

First of all, congratulations to all those coaches with individuals and teams who won conference and National championships this past March for indoor track and field. Also best of luck and Godspeed to everyone as they enter their respective conference meets coming up quickly.

As our collegiate outdoor track and field season is entering the championship portion of the schedule. I wanted to share a few thoughts for you to ponder this summer.

Thirty years ago when I first started coaching cross country track and field at Adams State University it seemed that the job was a breeze compared to the current job I have now. I certainly believe that is not just my perception but a real everyday workload that drives this feeling.

No one works harder than cross country/track & field coaches, as we are in season nearly nine months per year. In no way am I complaining or telling you something you don't already know, just stating a fact of our profession. Coaches spend great amounts of time on recruiting, budget management, home meet management, and the actual coaching of our teams, often with undersized staffs. We are typically pushing and wearing ourselves thin, going the extra mile to ensure a quality experience for our student athletes.

I wanted this letter to address this issue as I worry about most of us that love this profession of being a coach, not taking care ourselves the way we should. Successful coaches will tell you one of the keys to maintaining long term health, enjoying your home life and having continued success is to be able create a semblance of balance. Each of you has or must prioritize these tasks and pleasures to begin assembling what's important to you and what is not. We need to remind ourselves of these ideals nearly daily as we can lose perspective very quickly as we chase dreams of excellence with our student athletes.

Speaking from first hand experience, I can attest that our jobs are by their nature very difficult. Finding balance with these three seasons requires a high demand of intensity and focus from everyone involved. As our outdoor track and field season begins to wind down I encourage each of you to find time to enjoy yourselves, your family, and find more complete balance of those things that are important to you. I believe this will bring us back to the grind next year, more rested with quality experiences and ready to take on the new year.



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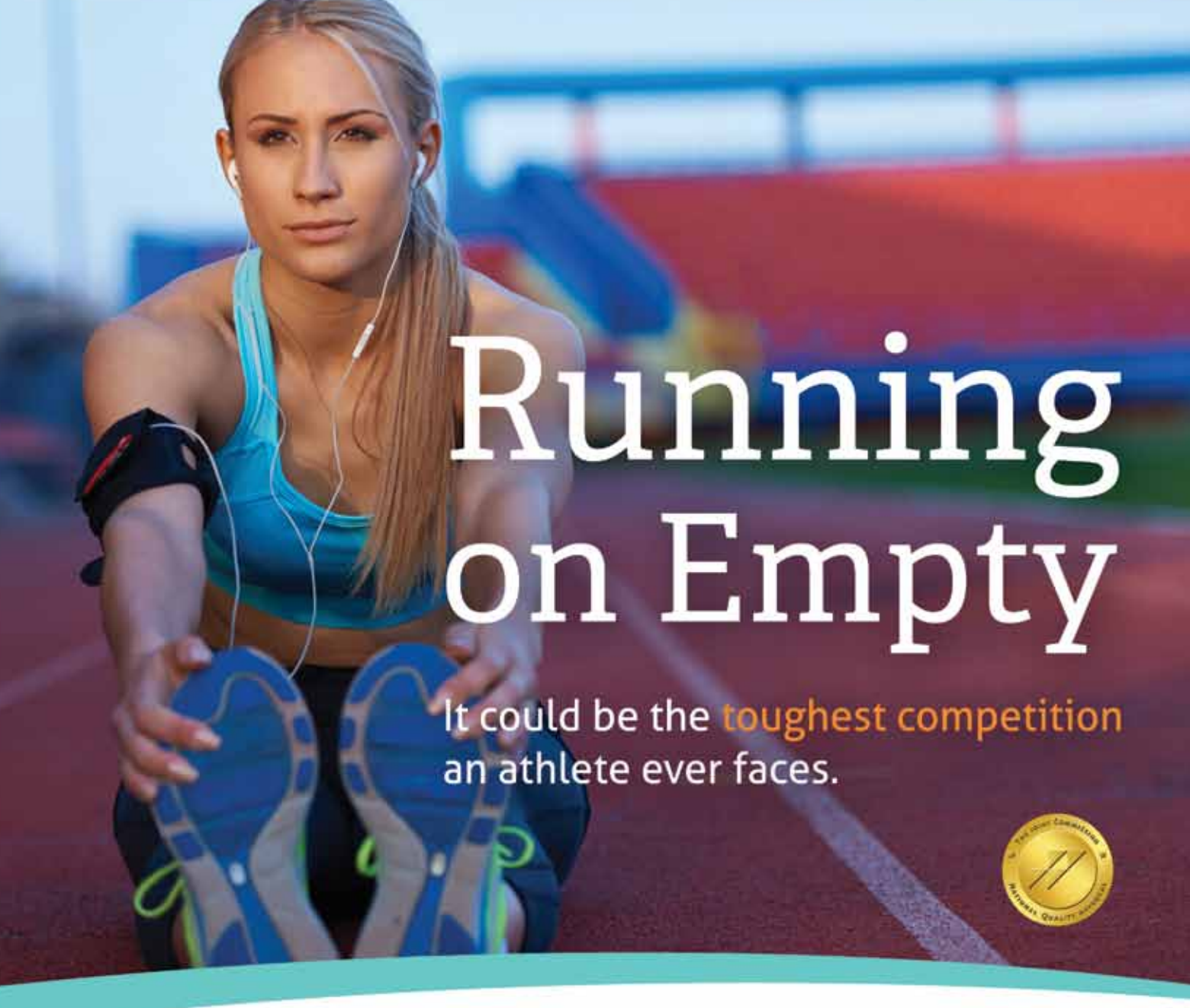
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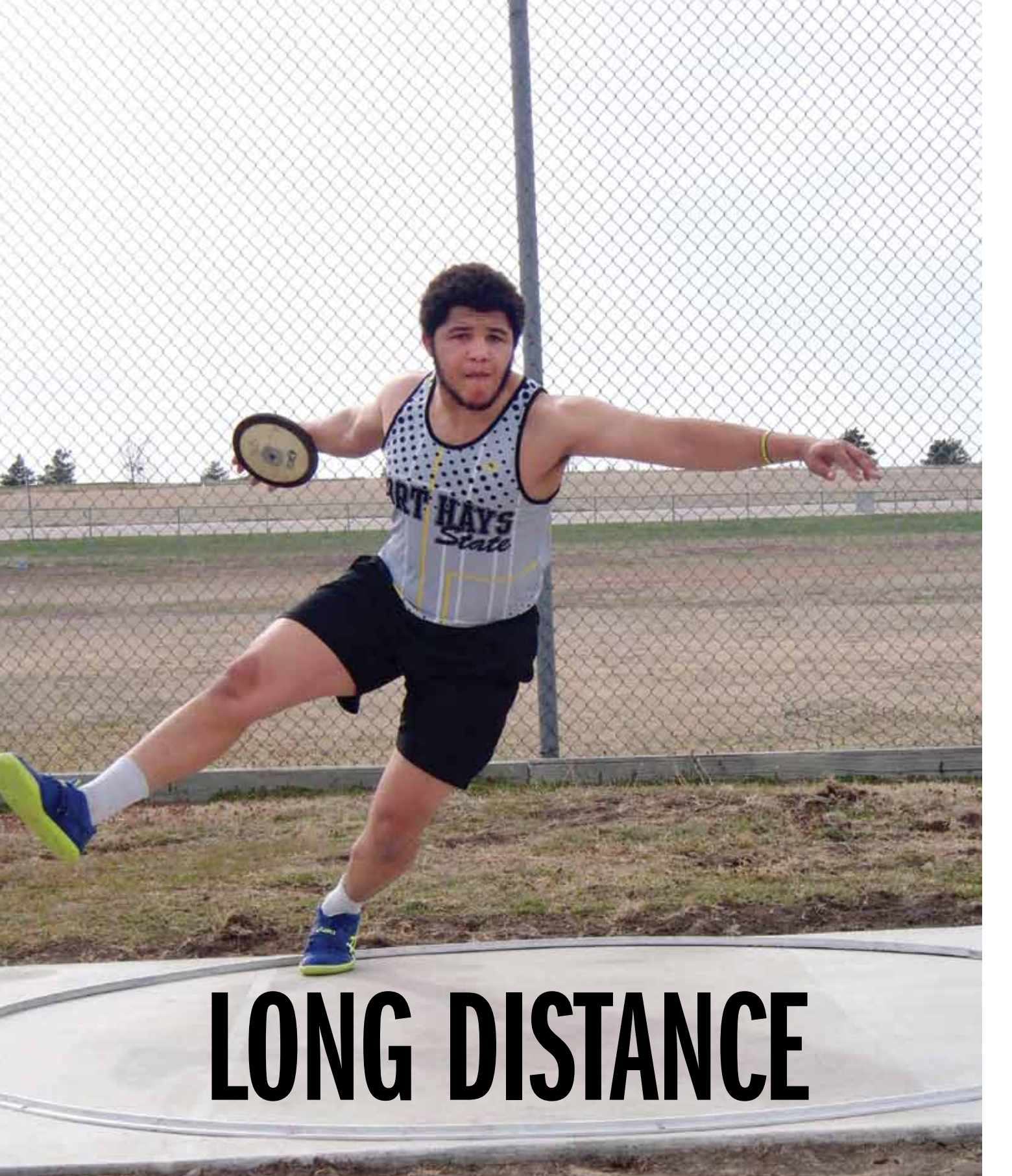
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LONG DISTANCE

BASIC AERODYNAMICS AND FLIGHT CHARACTERISTICS IN DISCUS THROWING

ANDREAS V. MAHERAS, PH.D.

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The discus is an extremely aerodynamic implement (Hubbard, 2000). This implies that, under certain conditions, the distance thrown can be increased or decreased significantly beyond or below to that expected in a vacuum or in still air. A notable example is from the men's discus final during the 1976 Olympic Games, where the gold medalist released his discus a significant 1.4 m/sec., less than the silver medalist (25.88 m/sec. vs. 27.28 m/sec., Terauds, 1978). However, aerodynamic factors dramatically affected the distance achieved by those two throwers. In a vacuum, the same author calculated that the silver medalist would have thrown 4.06 meters further than the winner. Indeed, the aerodynamic forces acting on the discus during its flight can decisively alter the course of its trajectory positively or negatively. So much so that the first author to publish scientific data regarding the effects of wind on the discus Taylor (1932) suggested that it would be unfair to allow records achieved under favorable conditions. Those favorable conditions are created as a result of fluctuations in the relative wind speed, primarily, and secondarily, the angle of release, the velocity of release, the attack angle, the inclination angle, the tilt angle, the rotation of the discus around its short and long axes, the effective mass of the discus and, its moment of inertia. During its flight the discus is influenced by gravity and the aerodynamic forces of lift, drag and pitching moment. Those forces act on the center of pressure (CP) which does not necessarily coincide with the center of gravity (CG) of the discus and is located somewhere in front of the CG. Drag is the product of the dynamic pressure (pressure in the front of the implement is greater than that in the rear), the cross-sectional area and a dimensionless drag coefficient. The other component, lift, is the product of the same elements but with its own dimensionless coefficient which measures the effectiveness of the implement to produce force perpendicular to the velocity vector. Those two coefficients along with the pitching moment coefficient depend on the attack angle. The angles of interest that are formed during the launch of the discus are those of release, attack, inclination, tilt, along with the pitching moment (figure 1).

LIFT GENERATION

The typical theory to explain how lift is produced, is with the use of the Bernoulli principle which states, there is a high air speed and low pressure on the top of the air foil (wing-discus-frisbee etc.) and a low speed and high pressure on the lower surface of the foil. The difference in pressure creates a positive, upward lift. However, this theory has been challenged as trivial, incorrect or incomplete (NASA). That is, it does not explain why the velocity is higher on top, and so the explanation of lift presented is no real explanation, or more precisely it is a trivial truism (Johnson & Jansson, 2015). Other theories that have been proposed include the Newton's third law theory, the "longer path" theory, the "downwash" theory, the Coanda effect theory, the Kutta-Zhukosky lift theory and the Prandtl Drag Theory. According to Johnson & Jansson (2015) none of these theories present a correct explanation of flight. They postulated that the aforementioned theories can be classified according to three conditions: trivial and correct, trivial and incorrect and, nontrivial but incorrect. They suggested that what is needed is a nontrivial correct theory and he offered a combination of the Bernoulli's principle and Newtonian physics theory as an explanation of how lift is generated. The detailed description of any of those theories is beyond the scope of this narrative.

ATTACK ANGLE

The optimum angle of attack of the discus depends on the angle of release. A negative angle of attack means that the initial direction of the center of gravity points upwards in relation to the long axis of the discus (figure 1), with the opposite being true for a positive attack angle. Negative attack angles are the predominant in high level throwing. Generally, the negative angle of attack should increase as the angle of release increases and decrease as the angle of release decreases. At an approximate release angle of 25 degrees, the angle of attack is at zero (Terauds, 1978). In still air, the optimized attack angle will be at -4 to -10 degrees (Soong, 1976; Frohlich, 1981; Hubbard & Cheng, 2007). Along with other release parameters, Chiu (2008), also calculated a -10.25° angle of attack as optimal for breaking the current men's world record, and that of -9.25° for breaking the current women's world record.

The magnitude of the lift, drag and pitching forces will strongly depend on the attack angle (figure 2). According to Seo (2013), Seo et al. (2012) and Ganslen (1964), lift increases linearly with the angle of attack up to the stalling angle which is at 30°. At that point the discus experiences a sudden decrease in lift and at 90° the lift force is zero. The drag force also increases with increasing attack angle from 0° to 90°. Ganslen (1964) showed that the sudden decrease in lift at 30° also coincides with the formation of a "turbulent wake" behind the discus. Discus performance will be improved if the discus has a relatively flat angle of attack. Once the discus develops an angle of attack to the relative wind, it will continue to exaggerate the "nose up" tendency which is termed as a positive pitching moment. This implies that a flight path initiated near the point of the stall angle for the discus, it will necessarily result in a stalled discus with high drag and low lift. Therefore, an optimum attack angle will allow the discus to complete its flight without stalling.

A term that has been used in reference to the attack angle, is the maximum lift/drag ratio and more specifically the attack angle at which that maximum ratio occurs. Taylor (1932) and Ganslen (1964) found that the maximum value of the ratio occurred at an attack angle of 9°. This value seems to be in conflict with a generally accepted negative optimal angle of attack. Hay (1985) attributed this discrepancy to the ever changing angle of attack during the discus's flight speculating that the optimum angle obtained at release will be the one that would yield the best results overall and not at a particular instant in flight. On the other hand Hubbard (1989) mentioned that the lift/drag ratio is a concept used in aircraft design to resolve issues related to the maximization of the steady cruising range of an aircraft. He stated that this ratio is irrelevant in a discussion of the transient behavior of a discus and that, as an aerodynamic term, it should disappear from the discus literature.

RELEASE ANGLE, ANGLE OF TILT, INCLINATION ANGLE

Terauds (1978) reported that the angle of tilt at release should be at 15° which he probably estimated from field or film observations. Soong (1976), found that with reasonable initial discus rotation, the release angle and the angle of inclination have a large effect on the range. At zero wind, the optimum combination of release angle and inclination angle is 35°/26° respectively if they vary independently. If they vary together, that optimum is at 33°. However, the former ratio will result in a 1.55 meters gain in range. Frohlich (1981) agreed that the optimum strategy in still air is to release the discus so that

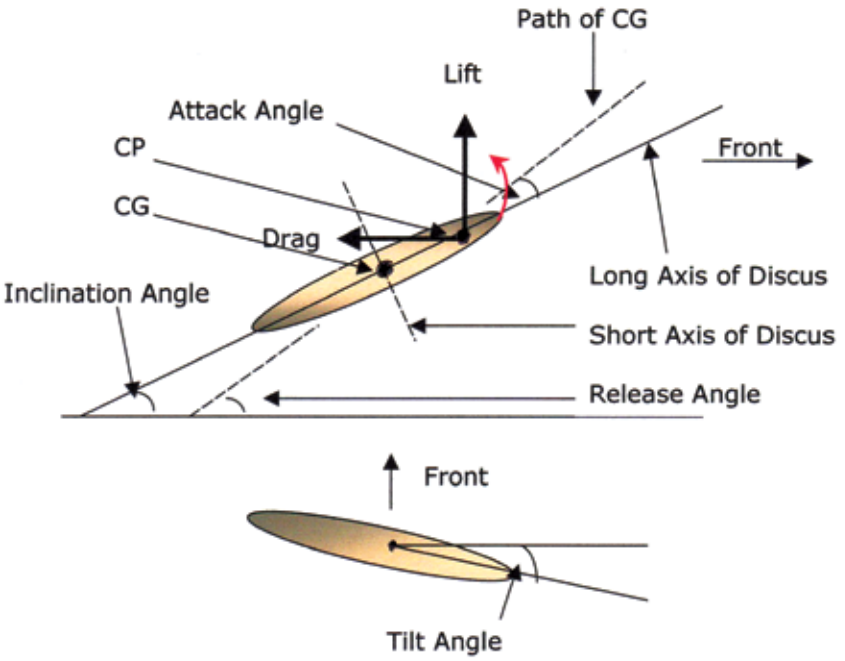


Figure 1. Aerodynamic forces and angles during the discus flight. Top: view from the side, bottom: view from the back. Red arrow depicts the pitching moment. CG=Center of Gravity, CP=Center of Pressure.

the inclination angle is about 5 to 10° less than the release angle. Although this results in negative lift during the early stages of the flight, it allows for a minimum of drag and optimum average lift throughout the upward part of the discus flight. Results from optimization studies that assumed a 0° angle of tilt, indicate that for elite throwers the discus should be thrown at release angles between 35-37°, inclination angles of 26-27°, and attack angles between -9 and -10°. Slightly higher release angles and more negative angles may be more suitable for throwers capable of lesser release speeds. Voigt (1972) claimed that by modifying his data to account for a -17° tilt angle at release, the range will improve by 2.7 meters. Hubbard & Cheng (2007) reported a maximum range of 69.39 meters with a men's discus released at windless conditions with a release speed of 25 m/sec. and a rotation of 6.6 rev/sec., is produced with an angle of release at 38.4°, inclination angle at 30.7°, and a tilt angle of 54.4° and attack angle at -4°. Deviations of several degrees of any of the first three values while holding the other two constant, will result in a minimum decrease of the range achieved, i.e., less than 39 cm. Larger departures, in the order of tens of degrees, will result in a range decrease of approximately 5 meters. Generally, range is most sensitive to the release angle and least sensitive to the tilt angle at release. For both men's and women's discuses, the optimal initial conditions of the angles of release, inclination and tilt, will vary significantly with wind speed.

There has been a considerable discussion regarding the need for the presence or not of a tilt angle at release. According to Hubbard & Cheng (2007) it is optimal to release the discus tilted significantly so that the lift vector can remain vertical throughout much of the flight, especially near the end of it. The angle suggested was at 54.4°. That angle will gradually decrease (see explanation of this effect under the discus rotation section below), from 54° and will remain at 15° before landing for a nearly flat impact. Though there may be an initial loss of early vertical lift from that initial tilt, the eventual plane reorientation to nearly horizontal overcomes that disadvantage because the tilt results in larger average aerodynamic forces. Regarding the optimum tilt angle, casual observations of throwers may show that they release the discus with a tilt angle quite smaller than 54°. It may be that the application of a theoretical optimum angle may in the end detract from the throwers' ability to maximize release velocity or other release parameters.

WIND VELOCITY

It is a well established fact that for both men's and women's discuses, longer throws can be achieved throwing the discus against fairly strong winds than with the wind or no wind (figure 3). The increases in range due to lift are larger than the decreases due to drag and the discus can always fly further in air than in vacuum (Hubbard & Cheng, 2007). In an early investigation, Taylor (1932), found that head winds between 7 and 8 mph were advantageous and that this advantage decreased progressively and at 14.5 mph became a disadvantage. He also found that tail winds of up to 14 mph were also detrimental to the range achieved. However, Frohlich (1981) using mathematical modeling, found that a discus will travel about 6 meters further if thrown in a 7.5 m/sec (16.8 mph) head wind than if thrown with the wind, and 8.2 meters further if thrown in a 20 m/sec (22.5 mph) headwind than with such wind. A properly thrown discus will always fly further if thrown against winds up to 20 m/sec (45 mph), than with it. This implies that long throws cannot be achieved against extremely strong winds. Theoretically, if the wind velocity is high enough, the discus will stop flying forward and it will actually travel backwards at some point during its flight.

Hubbard & Cheng (2007), employing a 3D dynamic model, reported a 10 and 14 meters advantage for men and women when throwing into a 5 m/sec (11 mph) headwind compared to a 10 m/sec. (22 mph) tailwind. Tutjowitsch (1976) found that if thrown at an negative angle of attack and at a release speed of 23 m/sec, the discus will fly 5.4 meters further if thrown into a head wind of 5 m/sec (11 mph). This value is close to Taylor's (1932) but quite less that that of Frohlich (1981). Unger (1977) claimed a linear increase in distance for head winds of up to 5 m/sec (11 mph) with a greater than linear relationship for higher wind speeds, although he provided no support for those claims.

Chiu (2008), employing mathematical modeling, estimated optimal performances when the wind speed fluctuated from -21 m/sec (-47 mph) to 12 m/sec (27 mph). He found that when the head wind was at 17 m/sec (38 mph) the male "virtual" record holder could throw up to 84.27 meters, approximately 10 meters fur-

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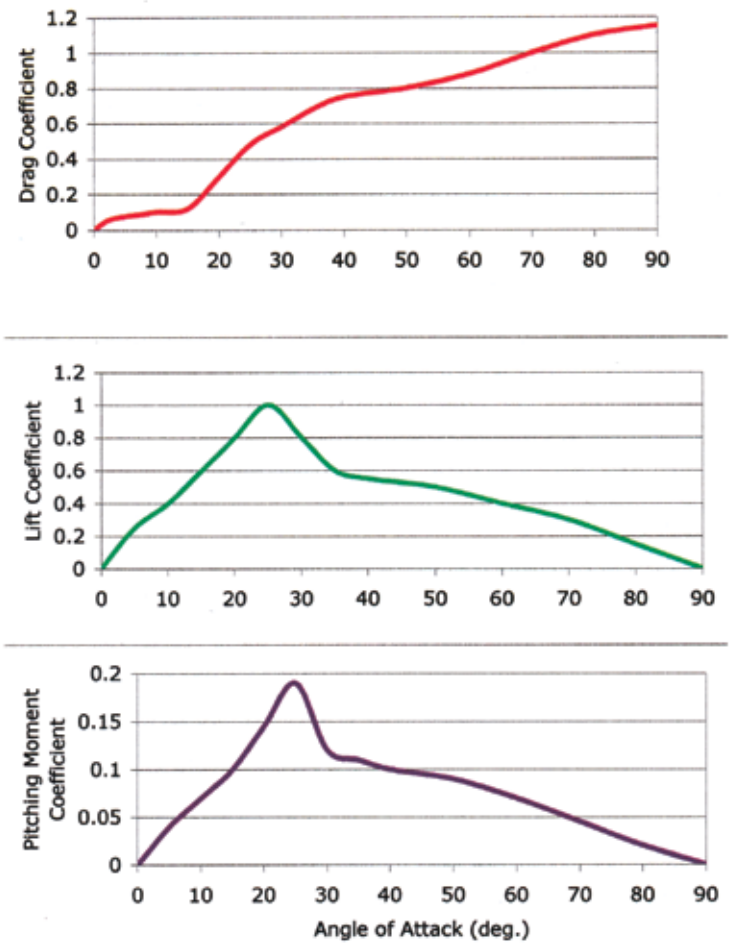


Figure 2. Dependence of aerodynamic coefficients on the angle of attack (adapted from Hubbard & Cheng, 2007).

ther than the current world record. When the head wind was over 17 m/sec., the range would decrease gradually. Similarly, for the female "virtual" record holder the distance would decrease at head wind speeds of over 13 m/sec (29 mph). Chiu (2008) also found that generally with increased tail wind, thrown distances for both males and females would decrease. However, he also reported a little known observation that, with tail winds of over 7 m/sec or 15.7 mph, (17 mph according to Frohlich, 1981), the ranges thrown for both males and females would begin to increase adding about 2 meters in a throw of 72.28 m., when the tail wind increased to 12 m/sec., (27 mph). At that tail wind speed, the throwing distance would be the same as when throwing in windless conditions. Chiu (2008) also reported that when the head wind was approximately 8 m/sec. (18 mph), both male and female "virtual" record holders would obtain their optimal throwing distance provided that the angle of release and the inclination angle were the same. On the other hand, with increased tail wind the optimal distance could be obtained only when the inclination angle was larger than the release angle.

Regarding the drag and lift coefficients, Frohlich (1981) stated that the measurement of those is probably not accurate for relative wind speeds of over 40 m/sec (90 mph) and that it would not be meaningful to perform any range calculations with wind speeds above 20 m/sec (45 mph).

THROWING IN THE WIND

For moderate winds, i.e., less than 20 m/sec (45 mph), a discus thrown with a tail wind must be thrown with a different strategy than a discus thrown in a head wind. Frohlich (1981) stated that with a head wind, the discus inclination angle, at release, should be about 10° to 15° less than the release angle so that during the majority of the flight the drag will be kept at minimum and lift at maximum. As the velocity of the wind increases, the release angle decreases making the discus trajectory flatter. This way the discus will not hover for too long and stall towards the end of its flight. On the other hand, for a discus thrown into a tail wind, the release angle should increase, the discus is thrown higher in the air. With tail wind velocities over 20 m/sec (45 mph), longer throws will be obtained if the discus is turned over so the discus catches the wind like a sail would. The worst possible conditions to obtain long throws is to throw in a tail wind of 7.5 m/sec. (17 mph). If the wind velocity is less than about 20 m/sec. (45 mph), longer throws can always be achieved by throwing against the wind (Frohlich, 1981).

Frohlich (1981) also observed that although the longest throws take place against strong winds, it is easier to obtain optimum performances when throwing in a tail wind, in the sense that it is easier or, less technique demanding, for a thrower to produce the optimum release parameters than if throwing in a head wind. For example, to obtain a throw within one meter of the optimum when throwing in a 10 m/sec (22 mph) head wind, the thrower should release the discus at an angle within ±5° of the optimum and at a discus inclination angle within ±3° of the optimum. When throwing in a 10 m/sec (22 mph) tail wind, the thrower could release the discus within ±6°, and ±15° of those angles respectively, to come within the same one meter of the optimum throw. This may imply that throwing in head winds may favor the experienced thrower due to the larger control required to achieve optimum performances. In addition, the effect of a head wind is enhanced as the discus spin increases with the higher the spin, the better the effect of a headwind (Hildebrand et al., 2009).

Hubbard & Cheng (2007) described what they termed a "slicing" strategy when throwing against strong headwinds of between 6 and 20 m/sec. (13-45 mph). In those conditions it is optimal to initially have the discus symmetry plane (an imaginary plane that equally divides the discus front and back) nearly vertical by decreasing initial inclination and increasing initial tilt substantially (>70°), although the release angle remains relatively constant near 35°. With strong tailwinds very high release angles are optimal. For example, with tail winds at 10.8 m/sec (24 mph), a strategy of 44.3°, 36.7° and 58.6° (release angle, inclination angle, tilt angle) will produce the same result as a 46°, 46.3° and 19.1° strategy, other factors being equal. For large tailwinds, a "kiting" strategy was proposed taking advantage of the fact that in extreme conditions the wind speed may be greater that the discus horizontal velocity.

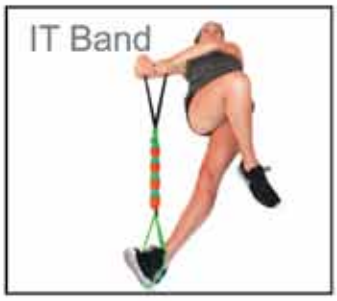
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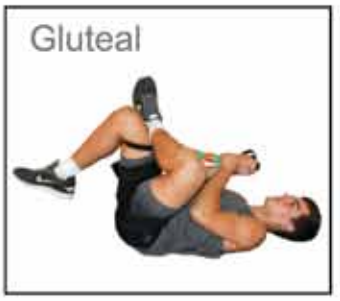


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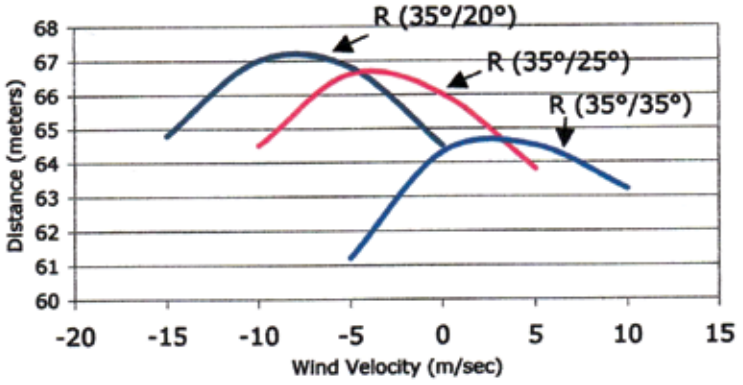


Figure 3. Effect of wind velocity (negative sign for headwind) on range (R) given angle of release/angle of inclination. Initial spin 36.9 rev/sec, release velocity 25.5 m/sec. (adapted from Frohlich, 1981).

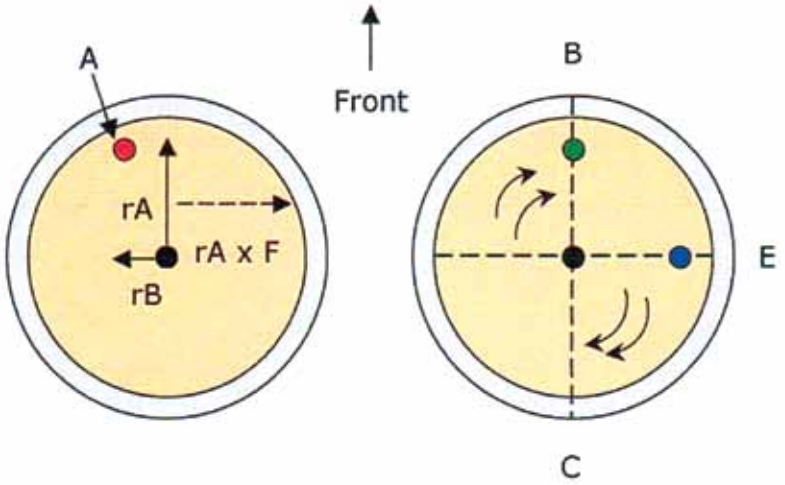


Figure 4. View from top. Effect of air on the clockwise rotating discus causing gyroscopic precession (rAxF), and lateral displacement of the center of pressure (A). In the right, a torque acting on point B (green dot), will cause a precession of that torque 90° towards the direction of rotation creating a torque vector applying a force upwards on point E (blue dot), causing the discus to rotate around the BC axis. (adapted from Bartlett, 1992).

In this case an initially positive angle of attack is chosen which makes both the angle of release and the inclination angle to increase. For a tailwind of 20 m/sec (45 mph), an angle of release at 62° with an inclination angle at 90° is proposed, with the entire flight essentially occurring at that extreme inclination angle, and the discus acting like a sail. Obviously, those optimal theoretical angles for high winds are extremely difficult or impossible to obtain by throwers.

Ganslen (1958) mentioned that a less able thrower will benefit more from a head wind of a given speed than a good thrower, because the percentage increase in the relative wind will be greater for the less able thrower than a thrower who can throw the discus at high velocities. Soong (1976), found that the head wind advantage is lost when the discus inclination angle is too high as it happens when both the angles of release and the inclination angle are 35°.

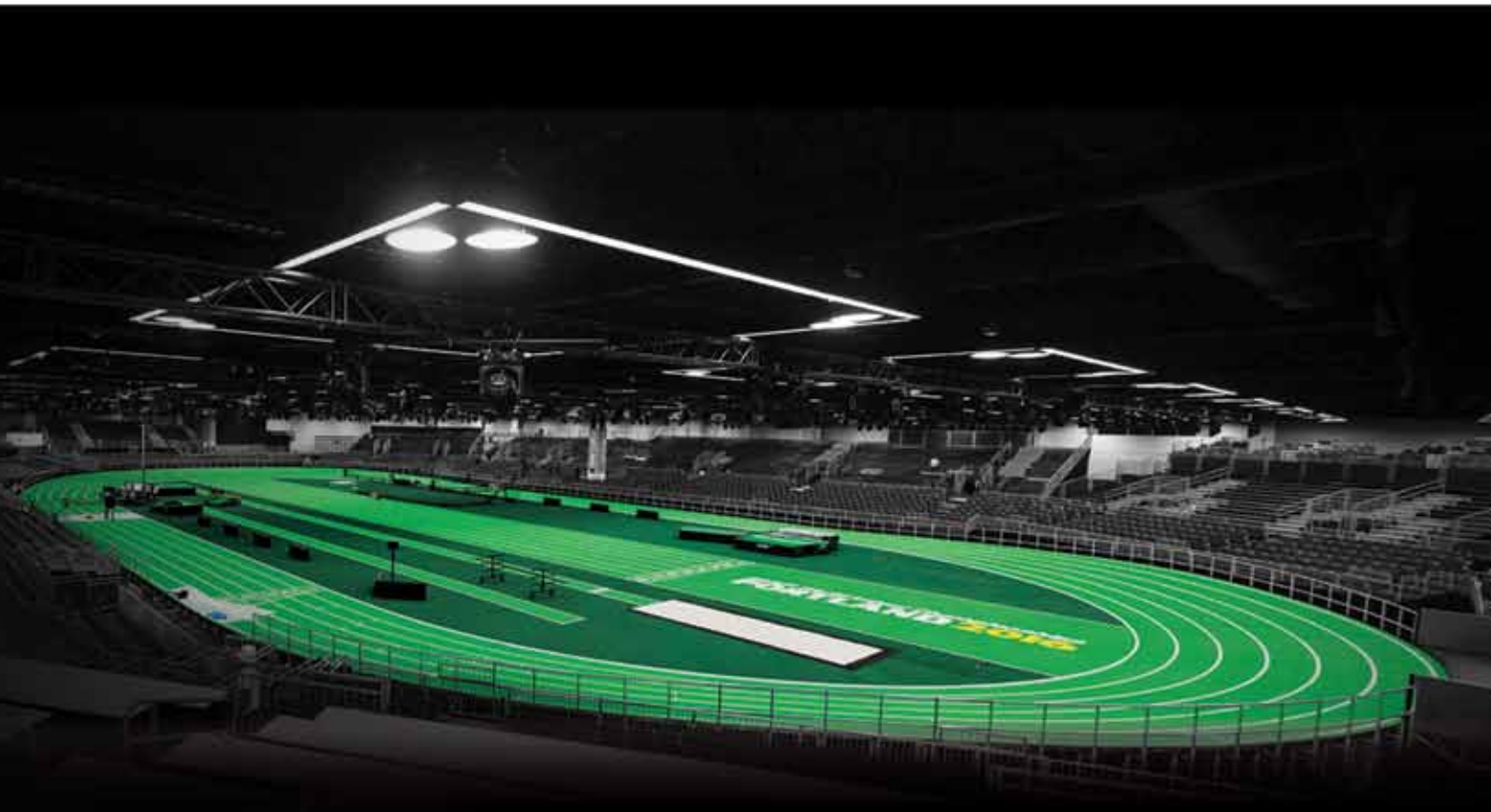
RELEASE VELOCITY

The paramount factor for optimum performance is the release velocity and all the efforts of the thrower should be geared towards enhancing that value. Aerodynamic forces become more important with increasing release velocity. Up to about 25 m/sec (56 mph), of release velocity, the range achieved is more or less the same whether the discus is thrown in windless conditions (still air) or in absolute vacuum, although a quite different angle of release should be used to obtain the optimal range for the throw. A discus will go further in still air as compared to a vacuum assuming that the release velocity is better than 25 m/sec., or if throwing against a strong wind (Frohlich, 1981).

DISCUS ROTATION

The most salient effect of the discus rotation around its short axis, is to stabilize its orientation during its flight. Frohlich (1981) reported that at the moment of release, the discus rotates at approximately 7 rev/sec. However, the effect of the discus rotation had not been studied in all past investigations, many of them assuming that both the pitching and the rolling rates the of the discus are invariable due to the stabilization gyroscopic effect of the discus spin. Soodak (2004) and Hubbard and Cheng (2007) recognized the apparent characteristic of the discus flight to exhibit a slow but uneven rolling of the discus with several degrees of roll occurring in typical flights. The women's discus exhibits a higher rolling rate than the men's. This rolling motion alters the direction of the lift vector and prevents the trajectory from occurring in a purely vertical plane. More recently, Rouboa et al. (2013) studied the aerodynamics of the discus with and without rotation. They stated that the rotation motion essentially influences the air resistance as it minimizes the influence of the drag forces and, thus allowing the discus to fly further. If there are no torques acting on it, the initial plane of motion of the discus is maintained throughout its flight. However, in reality, the rotation of the discus generates aerodynamic forces that apply torques which are small but not negligible. A careful observation of the discus during its flight shows that for a right hand thrower, the left side of the discus tilts or rolls progressively downwards at an angle that reaches approximately 10° shortly before the discus lands. This behavior of the discus occurs because the aerodynamic lift forces are larger on the forward half of the discus and tend to make the front edge move upwards. Because of the discus rotation, this upward torque creates a gyroscopic precession, a phenomenon occurring in rotating bodies in which an applied force is manifested 90 degrees later in the direction of rotation from where the force was applied. Therefore, the end result is the creation of a torque vector pointing to the right and causes the right side of the discus to go up (figure 4). Secondly, since the discus rotation causes the relative air velocity to be slightly higher on the left side of the discus

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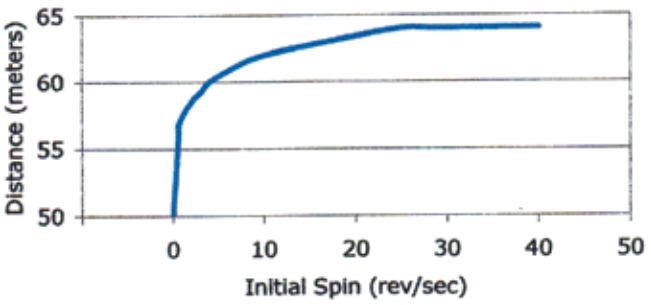


Figure 5. Effect of the initial rotation on the range. Angle of release=angle of inclination=35°, release velocity = 25.5 m/sec. (adapted from Soong, 1976).

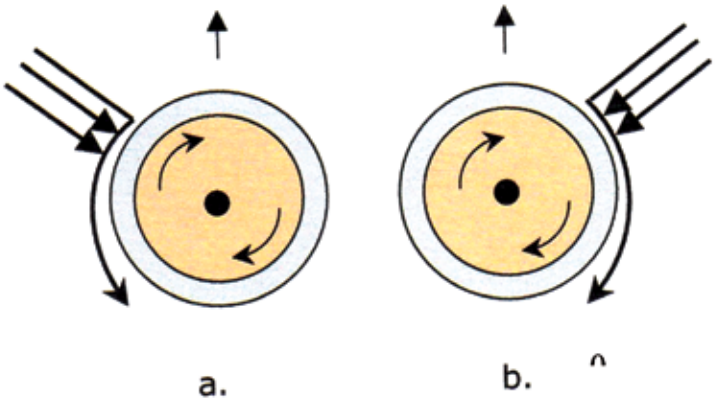


Figure 6. Effect on discus rotation of a side wind from the right (b) or left (a), for a right hand thrower.

(Magnus effect), the aerodynamic forces cause a lateral displacement of the center of pressure to the left. These forces create a torque vector pointing forward causing the front edge of the discus to pitch upward at about 1.5°/sec during its flight which results in a change in the angle of attack which in turn affects the magnitude of the lift later in flight. Those three moment components (i.e., higher forces on the front half, lateral displacement of the center of pressure and, change in the attack angle) will rotate the discus counterclockwise around its long axis, with the left edge moving downwards and the front edge pitching up (Bartlett, 1992). It will also slow the rate of rotation of the discus around its own axis, although that effect is negligible (Hubbard & Cheng, 2007). The latter authors also reported that optimal strategies and ranges for both men's and women's discuses depend on initial spin assuming a constant velocity and on release velocity assuming a constant spin. Frohlich (1981) mentioned that because of the symmetrical shape of the discus, a non rotating one would experience smaller aerodynamic torques than a rotating one and that this had caused an expert to suggest that a discus be constructed with a hollow rim filled with mercury in order to reduce that rotation after the release. However, a non-rotating discus lacks stability and will most likely wobble. Such a discus may experience less torque but it will also become less aerodynamic, and eventually the negative effects will outweigh the positive.

Rouboa et al., (2013) using computational fluid dynamics, studied the aerodynamic effects on the discus both with and without rotation. They found that the range of the discus was strongly affected by the drag coefficient, the initial velocity of release, the release angle and the direction of wind velocity. In turn, those variables change as a function of discus rotation. For a variety of angles of release and velocities of release they tested, the rotating discus had an advantage over the non rotating one. For example for release speeds of 25 m/sec (56 mph) and 27 m/sec (60 mph), a rate of rotation at 4 rev/sec, an angle of release at 34°, angles of attack varying between 0° and 90° and, a head wind of 10 m/sec (22 mph), there was a gain of the rotating discus of 2 meters and 5 meters respectively for those two release speeds. They also calculated that the rotation of the discus does not alter the vertical distance of the throw. However, those authors did not specifically mention whether the rotation of the discus affects drag, lift and pitch. Regarding that issue, Seo et al. (2012), found little difference between the aerodynamic coefficients of drag, lift and pitching moment whether the discus was spinning or not. Voigt (1972) reported a 3.75 meters increase in range if the spin was increased from 5 to 16 rev/sec. with a release speed of 20 m/sec.

Soong (1976) also tested the effect of the speed of rotation of the discus. He found that with a 25.5 m/sec. speed of release and a discus rotation speed from 0 rev/sec to 37 rev/sec, there was an increase of 13.76 meters attributed to the discus rotation (figure 5). Although he tested higher rotation speeds, he found out that values beyond the speed of approximately 37 rev/sec., will not change the range achieved, but that the pitching and rolling motions could be reduced. Hubbard & Cheng, 2007, argued that the optimal initial spin rates they calculated, using 3D models, of 4 rev/sec. and 7 rev/sec. for men's and women's discuses respectively, indeed allow for an advantageous orientation of lift later in flight something that much higher spin rates would probably not allow. Hildebrand et al. (2009) similarly found that the best throw is obtained at the highest spin rate. Their numerical results were very close to those of Soong (1976) although the former authors studied rotation speeds between 6.3 and 14 rev/sec. By the same token, for a men's discus spinning at 14 rev/sec., the optimal wind is a straight head wind (in line with the direction of the throw). At the same spin rate, a head wind at 50° from the right is optimal for the women's discus. As the spin rate decreases, the optimum wind direction generally shifts from a head straight wind (0°), to the right (90°) and the throwing range also decreases.

MOMENT OF INERTIA

The dimensions and the mass of the discus are specifically determined by the rules of the sport, but there are no specifics regarding the moments of inertia of the discus, which essentially means that there are no restrictions as to the distribution of the mass around the center of the implement. The force required to stop a rotating object depends on the product of the mass of the object and the square of the distance from the axis of rotation to the particles that make up the body ($I = m r^2$). The further the distribution of the mass from the center, the greater the moment of inertia of the rotating object. Inertia simply expresses the degree of resistance in altering the given state of an object. Discuses


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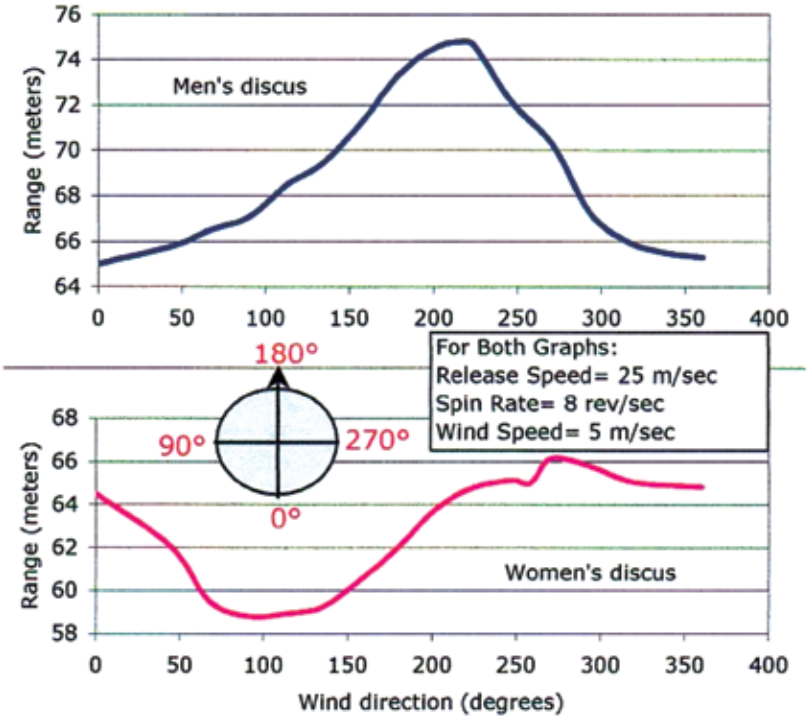


Figure 7. Effect of direction of wind on the range of the discus. 180°= straight head wind, 0°= straight tail wind. Left hand throwers subtract from 360°. (adapted from Hildebrand et al., 2009).

with large moment of inertia have most of their weight towards the edge of the discus. Assuming that adequate rotation is imparted on such a discus, it will be increasingly difficult to alter its state of rotation, i.e., to slow it down. Indeed, most discus throwers have a tendency to prefer throwing discuses in which most of the mass is concentrated toward the rim. The large moment of inertia of those discuses, that resists changes, make them less prone to adverse aerodynamic torques. Since a discus with large moments of inertia is less likely to spin out of its previous rotational plane, the highest density of the discus should be on its circumference (Hildebrand, 2001).

These days companies offer a plethora of discuses with a variety of weight distribution. The wise thrower will choose the discus that will suit her capabilities. More may not always be better when it comes to the moment of inertia of the discus. Soong (1976) studied the effect of the discus moment of inertia, as a function of the rate of discus spin, comparing two men's discuses, one with a 22.4 mm., rim thickness (most commonly used discuses) and another with 28.2 mm. The former presented inertia of 157.61 gm/cm/sec², while the latter, 182.5 gm/cm/sec². He found that the ratio of the moment of inertia to the weight of the commonly used discus, is already sufficiently high. Further effort in redistributing the mass will not produce significant improvement in the throw. The maximum distance advantage of the thicker rim discus was at the spin rate of 8 rev/sec., and it was about 44 cm, while at the speed of 4 rev/sec., the gain was 1 cm.

OTHER EFFECTS

Side Winds. Simulation research has not extensively studied the effect of side winds. Experience with throwing against head side winds strongly supports the advantage of those winds. In an observation of a number of practice throws, Pharoah (1957) speculated that the optimum wind direction is from 20° to the right of the throwing direction. Frohlich (1981) also mentioned that head winds blowing from the right side (right hand throwers) would allow for even longer throws than those obtained with direct headwinds. He suggested that in those conditions the thrower would want to release the discus with the highest point of its rim towards the direction of the wind. He further explained that with the wind being from the right, it will reach the discus at oblique angles, and that the relative wind velocity will be smaller compared to a direct headwind. This will cause both the drag and the lift to be reduced. However, longer distances may be obtained since some of the drag forces would act perpendicular to the direction of flight thus reducing their negative effect on the discus. In addition, Terauds has addressed that for a right hand thrower, the side wind from the right, would also serve to maintain the gyroscopic stability of the discus by enhancing the rotation of the discus since its right side moves with the wind (figure 6 b) rather than in opposition (figure 6 a). For left hand throwers, the same phenomenon is true for a wind from the left and a counterclockwise rotation of the discus. Hildebrand (2001) further mentioned that with headwinds, the discus rolls from a generally horizontal position to a nearly vertical one which tends to make it lose lift. His computer simulation showed that the head wind from the right is more beneficial because it hinders the rotation of the discus around its long axis (axis BC in figure 4), and preventing, or better delaying, the discus from assuming a vertical position.

Hildebrand et al. (2009) applied 3D simulation to study the optimal release conditions given a constant wind of 5 m/sec. (11.2 mph) blowing from a variety and all directions, for both the men's and the women's discus. Figure 7 shows the effect of the wind on the range. For the men's discus, a wind from the right at 40° in relation to the direction of the throw (220° in figure 7), was the optimal, given a release velocity at 25 m/sec., an angle of release at 33 degrees and an initial spin at 8 rev/sec. For the women's discus, a wind exactly from the right, 90° in relation to the direction of the throw, (270° in figure 7), was optimal, given 24 m/sec. release velocity, 41° angle of release and 8 rev/sec initial spin rate. According to those authors, for the men's discus, the result is a straightforward one in that a direct tail wind is the worst and a head wind from the right is the optimal. However, for the women's discus, the optimal wind comes from the right at a right angle to the direction of the throw (90°), with winds from the left being the worst. It is interesting to note that the results of Hildebrand et al. (2009) show that a women's discus will travel about the same with a direct tail wind or a wind from the right at approximately 30° in relation to the throw (210° in figure 7), assuming all other variables are constant. Also, based on the same results, for the men's

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discus, a thrower who is throwing the discus in a wind exactly from the right (90°), would gain about 1.2 meters if he adjusted his technique so that the direction of the discus flight shifts about 15° to the right (195° in figure 7).

Effects of Discus Area, Mass, Air Density. The effect of the aerodynamic forces is proportional to the quantity Area/Mass. In those quantities, the mass and area of the discus are fixed values, whereas the air density can fluctuate among places depending on temperature and altitude. Frohlich (1981) reported that, assuming same release velocity, lower effective mass discuses fly further, particularly in a head wind. In still air, for every kilo in mass reduction there are 47 cm. gain in distance, whereas in a headwind of 10 m/sec., (22 mph) the gain in distance is approximately 3 meters for every kilo in mass reduction. This implies that, if released at the same velocity, a women's discus will travel 47 cm. further than the men's in still air and 3 meters further in a headwind of 10 m/sec., due to the better overall aerodynamics of the reduced surface women's discus. When the effective mass is reduced, the thrower will need to reduce the release angle to obtain the optimum distance. Therefore, women discus throwers should release their discus several degrees smaller than the suggested optimum for the men's discus. Men discus throwers throwing at high temperatures and high altitudes should release at angles several degrees beyond suggested optimal. Hildebrand et al. (2009) also attributed differences between the men's and women's discuses, as to the optimal direction of the wind, to differences in the discus effective mass.

Better performances, though not significantly better, can be achieved at low temperatures (cold air is denser than warm air) due to the effect of air density on the aerodynamics. A discus will fly 13 cm. further at 0° C (32° F) than at 40° C. (104° F). Under the same conditions it will fly 90 cm. further with a 10 m/sec. (22 mph) headwind. For every 10 mm Hg increase in the atmospheric pressure there is an increase of 1.2 cm in distance if thrown in still air, and 8.1 cm. in 10 m/sec headwind. Differences in air density would cause a discus released at the elevation of Athens, Greece, to fly 19 cm. further than if released at the elevation of Mexico.

Effects of Gravity, Orientation and Release Height. Because the gravitational acceleration varies less than 0.5 percent among places on Earth, changes in that acceleration have little effect on discus range, a discus will fly 34 cm. farther at the equator than at the poles. Moreover, because of the earth's rotation, any projectile will travel longer if released eastward than westward, assuming no differences in any of the other factors affecting the distance thrown. The distances gained will be minimal though.

Regarding the release height, Frohlich (1981) reported that it appears that releasing the discus 1 meter higher will result in a 2 meter longer range. Since such increases in release height are impractical, those gains can be generalized and assumed to be approximately 10 cm for every 5 cm increase in release height.

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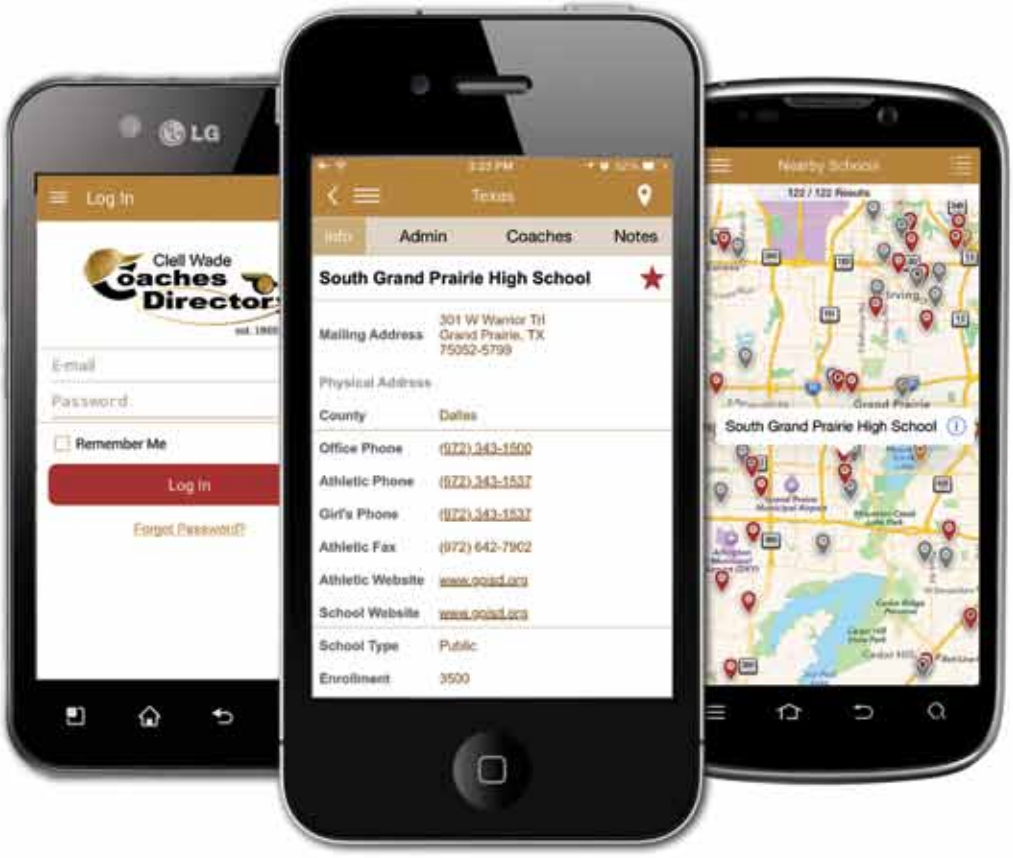
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ASSESSMENT

USE OF QUADRATHLON WITH COLLEGIATE TEAMS

DUDLEY, E., FREMD, E., LARSEN, A.

The Quadrathlon Test is a commonly used measure to evaluate power, speed and coordination among collegiate Track & Field teams. Originally devised in 1982 by Max Jones to test for explosive power improvement among the British National Team Throwers, it is now commonly used by sprinters, jumpers, hurdlers and combined event athletes. The simplicity and generality of the movements provides opportunity for intra-team competition among athletes from various event groups, and is often a marquee affair in fall training.

The Quadrathlon consists of four events — the standing long jump, the three jumps, the 30 m sprint, and the overhead backwards shot throw — that amass points similar to the heptathlon and decathlon, which can be combined to identify an overall winner.

TESTING PROTOCOLS & TEACHING CUES

STANDING LONG JUMP

While the standing long jump may be done on a variety of surfaces, testing of track and field athletes typically utilizes the long jump pit. The athlete may set up with the first knuckle of the big toe (the toenail) hanging over the edge of the sandpit. This allows the athlete to push off the edge of the runway without slipping on residual sand particles. Takeoff mechanics include appropriate loading mechanics, with the flexion at the hip greater than the flexion at the knee, full triple extension of the hips, knees, and ankles while simultaneously achieving a forwardly directed shin angle. This position should be dynamically loaded to derive benefit from the stretch shortening cycle. Aggressively swinging and punching the arms forward and upward will aid in distance as well. Landing mechanics are similar to running long jump, with feet together, and heels reached out slightly ahead of the center of mass for initial impact. Without the benefit of a running approach, athletes may not have sufficient momentum to slide through the hole made by initial imprints in the sand, and may have to compromise on landing to avoid falling backward and losing distance.

THREE JUMPS

A series of tape marks approximately 60cm (2 feet) apart is placed on the runway ranging from about 5-10m from the edge of the pit, depending on the abilities of the athletes. Athletes take three consecutive double legged jumps from their selected starting mark into the pit. Jumps must be continuous and feet must land parallel and simultaneously on each hop. Momentum and reactive strength are important qualities here. Full-footed, rolling (heel-to-toe) ground contacts are important for both maximizing performance and minimizing injury risk. Athletes must resist excessive forward rotations by maintaining good core activation and control, and guarding against excessive kyphotic curves in the thoracic spine by maintaining a "big chest."

30 METER SPRINT

One of the most variable and unreliable events of the Quadrathlon is the 30 m sprint. Traditional methods call for a coach to stand at the finish line and manually start a stopwatch the moment the athlete contacts the ground on the first stride and manually stop the stopwatch when the athlete's torso crosses the line. The advent of multiple new technologies offers the promise of enhanced reliability and automaticity. Proper acceleration and sprinting mechanics apply here, including forwardly inclined shin angles, postural alignment at toe-off, force application and knee lift symmetry, powerful arm drive, and concomitantly increasing stride frequencies and lengths.

A challenge for those wishing to include timing technology in their testing is comparing and interpreting results in the context of historical data. For example, the great Bill Webb, hall of fame former head coach at Tennessee, has compiled extensive data not only from his own athletes, but from professionals around the world, including Japan, East Germany, Sweden, Switzerland, Finland, Canada, Estonia, Belgium, and more. Admittedly, Coach Webb used the hand timing method outlined in the original test, leading to faster times than those who used automated technologies.

In the interest of being able to make comparisons between tests that used current technology and those that used hand timing, we sought to identify a conversion or offset that would allow us to rectify the two datasets. We used a Freelap Timing System, which initiated the timing function when pressure was released from a thumb pad. The timing interval ended when the athlete came in proximity of a transmitter cone set 30 m from the start. On each trial a coach who was familiar with the traditional manual timing protocol and who had been involved in previous years testing also recorded a manual time. Thirty Division I Track & Field Athletes used a three-point or four-point starting position to apply pressure to the thumb pad. Each athlete made two attempts, and all attempts that produced valid results for both timing methods were included in the analysis. This resulted in a total of 50 valid data pairs.

The average offset between Freelap and manual timing was 0.40 seconds. The standard error of the estimate was 0.014

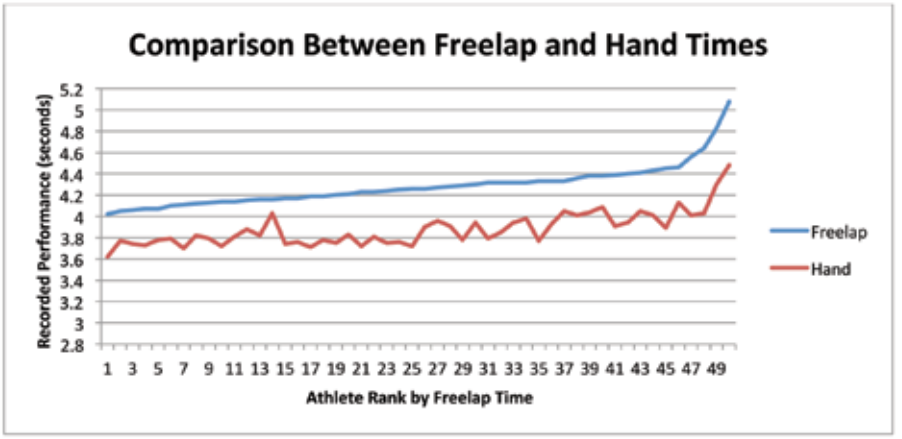
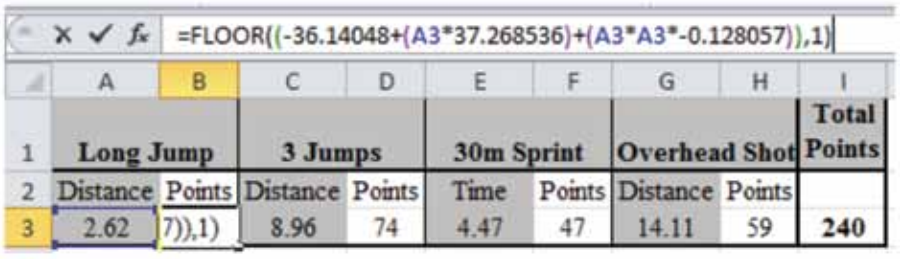


Figure 1. Comparison between Freelap and Hand Times showing consistent 0.40 second offset.



	A	B	C	D	E	F	G	H	I
1	Long Jump		3 Jumps		30m Sprint		Overhead Shot		Total Points
2	Distance	Points	Distance	Points	Time	Points	Distance	Points	
3	2.62	7)),1)	8.96	74	4.47	47	14.11	59	240

Figure 2. Sample scoring Excel spreadsheet with Standing Long Jump formula displayed in the formula bar.

The other formulas to type into excel, based on the above example are as follows:
Standing Long Jump: =FLOOR((- 36.14048+(A3*37.268536)+(A3*A3*-0.128057)),1)
Three Jumps: =FLOOR((-36.36996+(C3*12.478922)+(C3*C3*-0.007423)),1)
30 Meter Sprint: =FLOOR((209.70039+(E3*-36.94427)+(E3*E3*0.165766)),1)
Overhead Shot Throw: =FLOOR((-22.32216+(G3*5.8318756)+(G3*G3*-0.000334)),1)
Total Points: =SUM(B3,D3,F3,H3)

Once calculated for each of the four events, cells with formulas can be copied to other cells in the corresponding Points column.

	Men				Women		
	Mean	+/- SD	N		Mean	+/- SD	N
Overall	267	26	111		198	31	102
Jumps	263	29	46		198	27	44
Multi	279	19	8		201	17	10
Throws	265	29	26		171	36	21
Sprints	277	15	17		218	18	17
Hurdles	268	18	14		218	25	10

Table 1. Average Quadrathlon performance of all contributing members in the data set broken down by event group.

seconds (meaning that true average offset between Freelap and manual timing is almost certainly between 0.38 and 0.43 seconds, but 0.40 is a really good estimate!). Figure 1 visually shows the 0.40 second offset. Athletes are ranked from fastest to slowest according to Freelap time on the X-axis. The Y-axis shows both Freelap (blue) and hand (red) times for each athlete listed on the X-axis. Notice the significant noise in the hand timed data.

A 2010 study by Slawinski et. al looking at the kinematics of block starts showed similar results, with elite sprinters (10.06-10.43s for 100m) completing the first step in 0.446 seconds, while the well trained sub-elite sprinters in the study (11.01-11.80s for 100m) were nearly identical with a first step time of 0.440 seconds.

When a standing start was used, first step times reported by Dysterheft, et al. were 0.34 seconds. A three-point start, the most commonly used starting technique in the Quadrathlon 30 m sprint, would be expected to fall between these results.

OVERHEAD SHOT THROW

Competition weight shots are used – 7.26kg (16lbs) for the men and 4kg (8.8lbs) for the women. For this test the athlete will stand with both feet on the toe-board facing away from the throwing direction. The athlete grabs the shot with both hands cupped slightly on the underside of the ball. After lowering the shot between the legs and loading the hips, knees, and back, the athlete drives upward and backward to catapult the implement out into the landing area. While the rules for following through vary, with some programs require athletes to remain on their feet while others will count throws in which an athlete, after landing feet first, falls or rolls onto his or her back. Athletes will travel backward off the toe board and should not attempt to remain balanced on top of their perch. When loading, the athletes should again hinge primarily at the hip and secondarily at the knee, similar to a hang clean or kettlebell swing. The athlete should actively drive the ball back between their legs and try to "hit themselves in the butt" to complete the loaded position. From here the athletes

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	Men				Women		
	Mean	+/- SD	N		Mean	+/- SD	N
Overall	272	25	52		206	29	44
Jumps	274	22	17		207	30	19
Multi	290	15	5		211	19	5
Throws	264	33	14		176	24	8
Sprints	280	17	9		225	15	8
Hurdles	263	25	7		218	23	4

Table 2. Average Quadrathlon performance of top performing members – those who made the podium at their respective conference championships or qualified for the NCAA Preliminary Round.

	Men				Women		
	Mean	+/- SD	N		Mean	+/- SD	N
Overall	263	26	59		192	32	58
Jumps	256	31	29		191	23	25
Multi	262	11	3		192	7	5
Throws	260	28	12		168	42	13
Sprints	274	13	8		212	18	9
Hurdles	273	8	7		217	29	6

Table 3. Average Quadrathlon performance of athletes who scored between fourth and eighth place at their respective conference championships.

Table 4. Estimated Minimum Thresholds for success at the mid-major Division I or a competitive Division II team.

	Men	Women
Jumps	216	158
Throws	224	113
Sprints	257	188
Hurdles	215	180
Pole Vault	200	166
High Jump	231	150
Long Jump	275	168
Triple Jump	231	157
Multi	248	183
Javelin	#	142
Discus	240	139
Hammer	219	184
Shot Put	213	55
110H	266	180
400H	252	#
100m	257	205
200m	249	192
400m	257	177

 # = Insufficient data from which to draw inferences

should sit back, or unseat slightly so that the backward component of the trajectory comes not from hyperextending the back or flexing the elbows. The extension should sequence from proximal to distal, hips before hands. Arms should generally remain straight all the way through release.

The movements used in these tests, while general and foundational in nature, still experience a significant learning effect. Therefore, consideration should be given to teaching and using these movements in training prior to performing the Quadrathlon Test itself.

SCORING

Events may be scored by either table or equation. Equations can be easily set up in Microsoft Excel to automate the scoring process. The scoring formulas for use in excel are illustrated below.

The following example calculates the score for the Standing Long Jump in cell B3. After recording the distance (in meters) in cell A3, the formula is typed into the formula bar as shown (Figure 2). The command FLOOR simply rounds the result down to the nearest whole number, indicated by the ",1" at the end of the formula.

TALENT IDENTIFICATION

The overall Quadrathlon score may be considered a proxy for athletic ability, insofar as the athletic ability in question is highly dependent on the qualities of linear speed, speed-strength (power), and elastic or reactive qualities. Additionally, fall testing often coincides with early decision timelines for roster spots (i.e. tryouts). The test may be used to get a rough estimate of potential. It should be noted, however, that successful performances in the Track & Field events have been achieved following a wide range of Quadrathlon scores recorded in the fall. The following data represents the Quadrathlon scores that were achieved in the fall and the corresponding level of achievement during the following spring track seasons for two mid-major Division I programs. It is the estimation of the authors that performances in mid-major Division I conferences is similar in many respects to those posted in the top Division II conferences. Therefore the data may be of interest to around 260 Division I mid-major and 130 Division II programs.

The average performance to be a contributing member of the team — defined as scoring points in the conference championship – was 267±26 (M±SD) for Men and 198±31 for Women. Table 1 shows the average performance of all contributing members in the data set broken down by event group.

As expected, the top perform-

ers (Conference Podium or NCAA Preliminary Round Qualifier) tended to score higher than the nickel and penny performers (fourth through eighth place at Conference). Tables 2 and 3 show the average Quadrathlon performances for top performers and nickel and penny performers. Though the mean performance differs between high and low performers, there is significant overlap in individual scores recorded and on-track performances at both levels. For example, a male pole vaulter made the podium after scoring only 236 points in the Quadrathlon, while another vaulter failed to make the podium after scoring 284 points, which is higher than every other podium vaulter in the data set except one.

Despite the broad range of scores that ultimately may lead to success, Quadrathlon testing is often used to make early season decisions regarding tryouts and roster spots. Table 4 shows the estimated minimum thresholds that should be achieved during fall testing to be a potential contributing member of a mid-major Division I or a competitive Division II team in the spring. Nine out of ten athletes who ultimately end up scoring in conference post scores at or above these levels.

EVALUATION AND PLANNING OF TRAINING

The Quadrathlon is a useful way to track the development of athletic ability over time. The most useful comparisons are made from year to year, if testing is done at a similar time of the season under similar conditions. Acute training effects can enhance or depress individual event results, making it difficult to compare results achieved at different times and phases of the year.

In planning training, athletes who fall above average on the Quadrathlon test demonstrate untapped potential, but lack event specific preparation. Focus should be shifted to event specific activities such as technical mastery and specific strength. Athletes who fall below average relative to their level of on-track success demonstrate good event execution. A balanced approach that includes a focus on developing basic qualities of speed, power, and strength should be maintained. Males scoring over 300 points and females scoring above 220 points should be expected to make and appearance at the NCAA Preliminary Round, as these are considered very strong marks. Coaches failing to qualify athletes at this level should consider enrolling in one of USTFCCCA's many Track & Field Academy courses.

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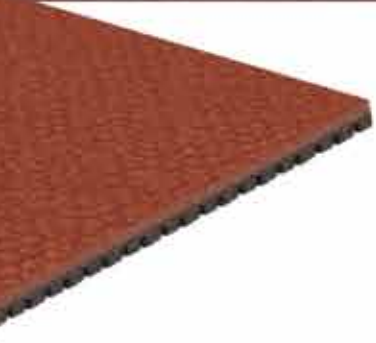


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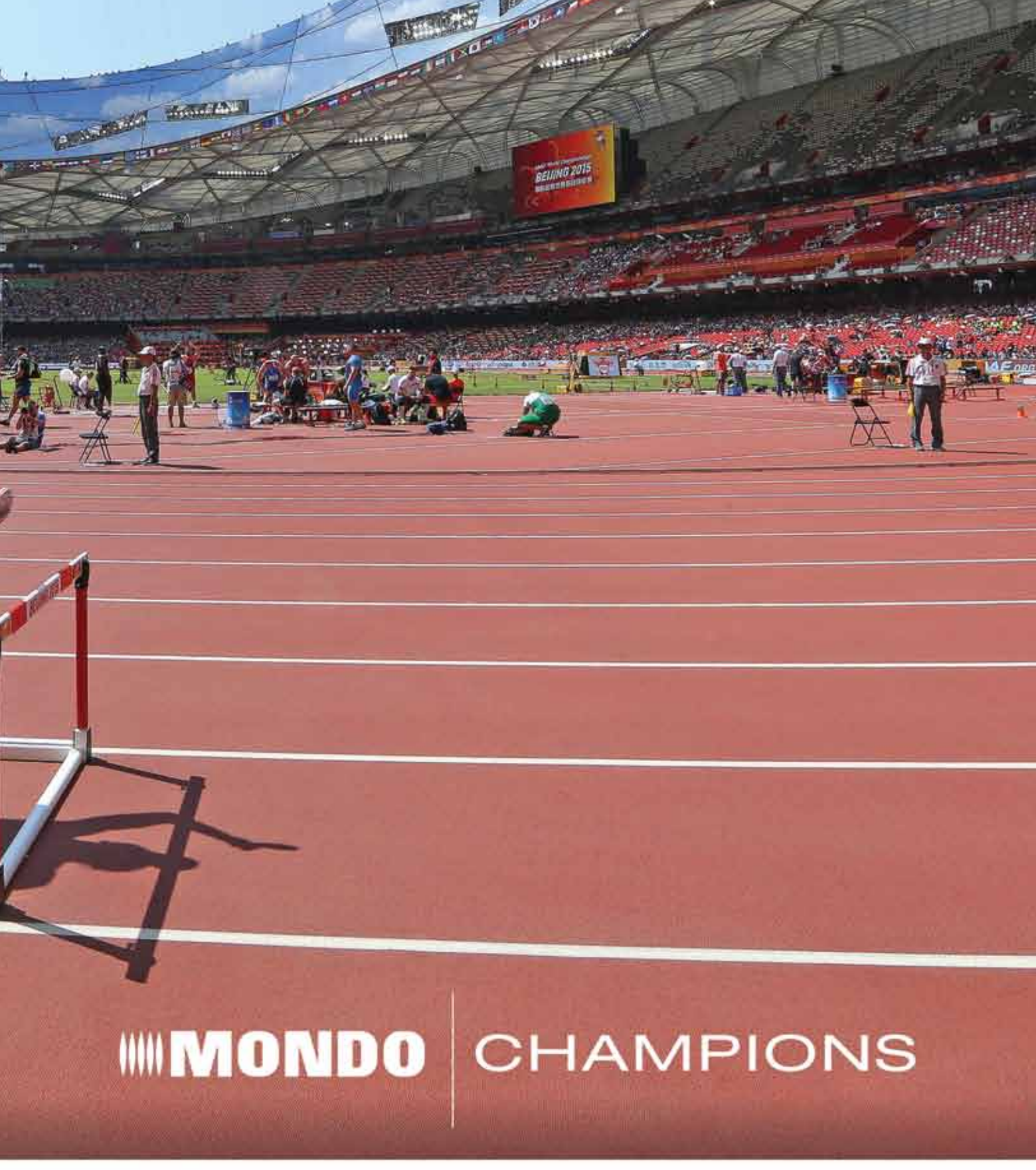
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Body Composition

METHODS AND IMPORTANCE FOR PERFORMANCE AND HEALTH

DONALD R. DENGEL, PH.D A., OLIVIA H. DENGEL B

The measurement and understanding of the basic morphological characteristics of the athlete is the foundation on which a training process may be built. Specific anthropometric characteristics are needed to be successful in certain sporting events. The use of body composition analysis to determine the amount of muscle and fat mass is as important as the physique of an athlete and is becoming a standard procedure that helps to improve and optimize the athlete's training process. Many collegiate, and even some high school, athletic programs routinely measure body composition of their athletes in an attempt to determine the optimal weight for performance. Given the numerous methods used to determine body composition, many coaches and athletes are unaware of the limitations of the methods they are using to make these measures. Additionally, few coaches or trainers are aware of what levels of fat

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mass, lean mass or percent body fat are normal for the athletes they are working with. Therefore, the first step in using body composition analysis to optimize an athlete's potential is to understand the limitations and positive elements of the methods being used to measure body composition.

Unlike some sports, track and field athletes come in a variety of shapes and sizes, as well as body composition. However, within a given track and field event the athletes competing in that discipline have very similar physiques and body compositions. Some events in track and field are considered gravitational in nature where total body mass restricts performance due to mechanical or gravitational reasons (e.g., high jumping, distance running, etc.) (Auckland et al., 2012). In these events, some athletes may resort to different methods to reduce or maintain a low body mass to gain a competitive advantage. However, having a low body mass does not always guarantee success in these events and in some cases an extremely low body mass may, in fact, be harmful. For example, an athlete may restrict their diet and not have adequate calcium intake, which will ultimately result in very low bone mineral density leaving an athlete with poor bone health and more prone to injury. On the other end of the spectrum, there are other events in track and field where greater total body mass, especially muscle mass, may be an advantage (e.g., shot put, hammer throw, etc.). Athletes in these events may resort to different methods to gain mass. Again, the addition of more total body mass in these athletes does not always guarantee success and sometimes can lead to imbalances in muscle composition leading to injury. The different competitive and health imperatives present a conflict for some track and field athletes, for whom eating disorders are exacerbated. Therefore, an important step in maintaining a track and field athlete's health and performance is the ability to accurately measure and assess an athlete's body composition. This article explores the various methods used to determine body composition, as well as the ranges in percent body fat that exist in track and field athletes.

The assessment of an athlete's physique and body composition to gain a competitive advantage is not a new idea. On the contrary, the concept of analyzing an athlete's physique has been around since the ancient Greek Olympic Games. Some might say the Greeks were obsessed with an athlete's physique, often depicting athletes in statues and vases. The Renaissance period led to an era of advanced study in the dimensions of the human body. Individuals such Leonardo da Vinci, not only extensively painted and sculpted the human figure, but also made detailed measurement of the anatomical proportions. Today there are a number of tools at our disposal, not only to measure the physique of an athlete, but also the specific amounts of muscle, fat and bone (i.e., body composition). To a large degree, an athlete's body type or build is limited by what they have inherited from their parents. This does not imply that there is nothing that can be done to change or improve themselves. While body type or build can only be altered slightly, substantial changes can occur in body composition with diet and training. These changes in body composition can be of major importance to achieving optimal athletic performance.

METHODS OF BODY COMPOSITION ANALYSIS

The oldest method of evaluating an athlete is simply looking at the body size, or the height and mass, of the individual. The distinctions of being classified as short or tall, large or small, heavy or light, depend entirely on the sport. A height of 188 cm (74 in) would be tall for a distance runner, but the average height of a decathlete (Table 6). Similarly, a weight of 78.9 kg (174 pounds) would be an average weight for a sprinter, but too heavy for a distance runner (Table 4). Therefore, body size must be considered relative to the event that the athlete participates in. The use of body size is frequently used by doctors and insurance companies, etc. to gauge the health of an individual. By taking the weight of an individual in kilograms and dividing it by the height in meters square you can determine the body mass index (BMI) of an individual. In males, a BMI greater than 25 kg/m2 is considered overweight. This method has limitations, for example if we look at decathletes we would find athletes who are considered overweight by this method. Obviously, the problem with using BMI in athletic populations that carry considerable amounts of muscle is they appear to be overweight using this simple system. This problem is even more evident in professional football players where almost the entire National Football League is considered overweight and a large number of players are considered obese (BMI >30 kg/m2) (Dengel et al., 2014).

Knowing only the weight of an athlete often provides a minimum of what an athlete or coach needs to know to develop an effective training program. Body composition analysis provides additional information to both the coach and the athlete. For example, to know that an athlete has a total weight of 200 pounds provides us with very little information of the quality of the 200 pounds. Body composition analysis could tell that coach that of those 200 pounds, 10 pounds are fat and the remaining 190 pounds are fat-free mass (i.e., muscle and bone mass). This provides both the coach and athlete with considerably more insight into the athlete's body. In

Table 1. Proposed body fat percentages for males and females

Category	Males	Females
Essential fat	2-5	12-15
Athletic population	5-13	16-20
Good	14-17	21-24
Acceptable	18-25	25-31
Overweight	>25	>32

Adapted from Williams, M.H., Anderson, D.E., & Rawson, E.S. (2013*). Nutrition for Health, Fitness and Sport* (10th ed.) McGraw Hill.





this example only 5 percent of this athlete's body weight is fat, which is about as low as any male athlete should go (Table 1). This athlete would then realize that his body composition is ideal, and he should not try to lose weight, even though he may be overweight by the standard height-weight charts. This example shows the value of utilizing body composition analysis instead of just a scale.

Currently, there are a number of methods and techniques for the estimation of body composition, ranging from simple field methods (i.e., skinfold measurements) to more advanced laboratory methods (i.e., dual energy X-Ray absorptiometry [DXA], underwater hydrostatic weighing). Before selecting a method, the coach or athlete should consider the availability of the necessary equipment, financial costs, safety precautions and accuracy of the method. Regardless of the cost or degree of accuracy it is important to remember that the measurement of body composition is not an exact science. All methods are prone to some degree of error. Therefore, it is important for the coach and athlete to think of the measurement of body composition as a range that is associated with the error of the measurement versus a precise value. This paper will explore the different methods of determining body composition and will give the values found in various track and field athletes. It is important to remember that the values reported in this paper are from elite and Olympic caliber athletes. Therefore, care should be used when comparing these values to high school or even college athletes. In addition, though we give a single value it is important to look at this value as the midpoint of a range. For example, if the percent body fat value for male sprinters is 9.1 percent, one should think that the range would be about 2 percent above and below this value. So male sprinters would have a range between 7.1 percent - 11.1 percent. In looking at Table 2, you can see that the two studies listed on male sprinters report percent body fat values of 8.4 percent and 9.8 percent.

One important thing about understanding body fat in the human body is that body fat really consists of two unique areas: one called essential body fat and the other termed storage fat. For health purposes, the body has a need for a certain level of body fat that is present in nerve tissues, bone marrow, and organs (all membranes). The other location of body fat in our body is the storage area. This represents an energy reserve that accumulates when excess energy is ingested and decreases when more energy is expended than consumed. In males, essential body fat is approximately 2-5 percent of total body mass for men and for women it is approximately 12-15 percent of total body mass (Table 1). Women have more essential body fat than men because of childbearing and hormonal functions. In general, the total body fat percentage (essential plus storage fat) is between 18 percent and 25 percent for men and between 25 percent and 31 percent for women (Table 1). Though percent body fat for athletic populations is listed between 6 percent and 13 percent in males and 16 percent and 20 percent for females, different sports have different body composition requirements. In some contact sports such as football, a higher body weight is sometimes seen as an advantage while in sports such as gymnastics, basketball and other weight-bearing activities, a lower body weight and high power-to-weight ratio are extremely important. Therefore, in these sports both low body fat and low body weight are necessary. Even in a sport like football there is a wide range of acceptable body fat percentages (Dengel et al., 2014). In football the desired body fat percentage was dependent to a large degree on the position of the player with wide receivers having significantly lower body fat percentages than lineman and even linebackers (Dengel et al., 2014). Track and field is much like football in that there is a wide range of body fat percentages in the athletes that participate. The body fat percentage in track and field athletes is dictated in a large degree to the events that the athlete participates in. It should be noted that there is no true accepted percentage body fat standard for the various events that make up track and field. An athlete's ideal body composition should be discussed on an individual basis with the coach, physiologist and nutritionist or dietician. In addition, body weight and body composition should be discussed in relation to functional capacity and exercise performance.

Before discussing the body fat percentages of track and field athletes let's first examine the different methods of determining body composition. When examining the various method to estimate body composition it is important to remember that the body is actually made up of a variety of different types of tissues and fluids. Whatever type of method is used

Table 2. Body Fat Percentages of Male and Female Sprinters

Category	Events	Caliber of Athlete	Sex	Number in Study	Method	Age (yrs)	Mass (kg)	Height (cm)	%fat	Reference
Sprinters	100m, 200m, 400m 110m hurdles, 400m hurdles	U.S. Junior Olympic	Male	24	UWW	17.8	70.6	179.6	8.4	Thorland et al., 1981
Sprinters	100m, 200m, 110m hurdles	1968 Olympics	Male	79	Anthro	23.9	68.4	175.4	9.8	de Garay et al., 1974
Sprinters	Unknown	U.S. Junior National	Female	4	UWW	13.5	50.1	161.5	10.7	Wilmore et al., 1974
Sprinters	Unknown	U.S. National	Female	4	UWW	18.3	57.8	171.5	11.1	Wilmore et al., 1974
Sprinters	100m, 200m, 400m, 100m hurdles, 400m hurdles	U.S. Junior Olympic	Female	26	UWW	16.7	56.4	167.9	13.4	Thorland et al., 1981
Sprinters	100m, 200m, 80m hurdlers	1968 Olympics	Female	28	Anthro	20.7	56.8	165.0	13.7	de Garay et al., 1974
Sprinters	100m, 200m	Collegiate	Female	24	Anthro	20.1	57.0	165	19.4	Malina et al., 1971

Anthro, athropometrics/skinfolds; UWW, underwater weighing

Table 3. Body Fat Percentages of Male and Female Middle Distance Runners

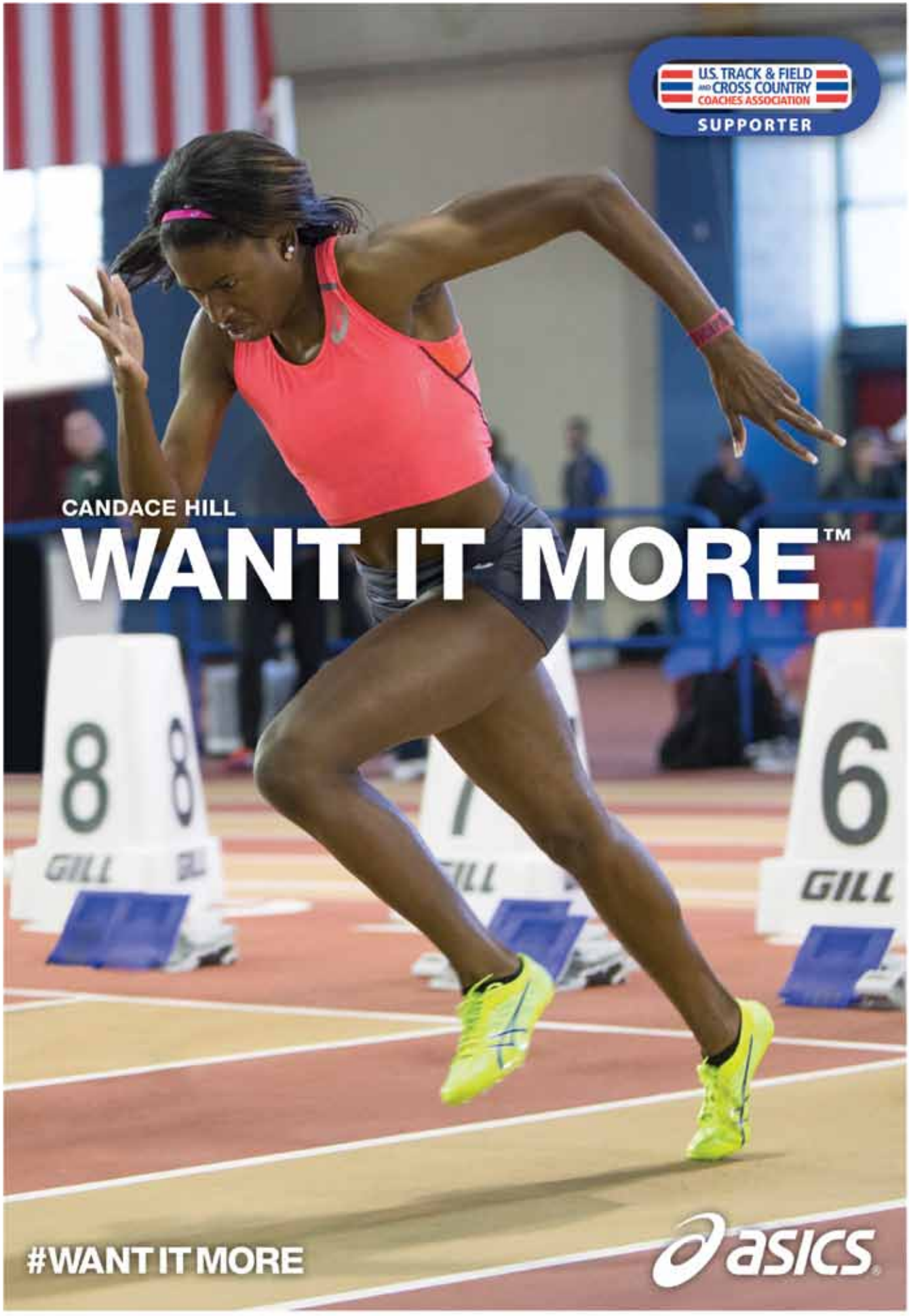
Category	Events	Caliber of Athlete	Sex	Number in Study	Method	Age (yrs)	Mass (kg)	Height (cm)	%fat	Reference
Middle Distance	800m	Elite Finnish	Male	6	Anthro	24.6	72.3	179	12.4	Rusko et al., 1978
Middle Distance	800m, 1500m	1968 Olympics	Male	41	Anthro	22.9	65.0	177.3	8.8	de Garay et al., 1974
Middle Distance	800m, 1500m	U.S. Junior Olympic	Male	47	UWW	17.7	62.9	181.7	7.3	Thorland et al., 1981
Middle Distance	800m, 1500m	U.S. Elite	Male	42	UWW	21.7	68.7	181.4	8.6	Boileau et al., 1982
Middle Distance	800m, 1500m, 3000m	U.S. Junior Olympic	Female	41	UWW	16.6	51.4	166.5	12.5	Thorland et al., 1981
Middle Distance	400m, 800m	1968 Olympics	Female	18	Anthro	20.0	54.3	166.9	10.9	de Garay et al., 1974
Middle Distance	400m, 800m, 1500m	Collegiate	Female	12	Anthro	19.9	53.0	162	19.1	Malina et al., 1971

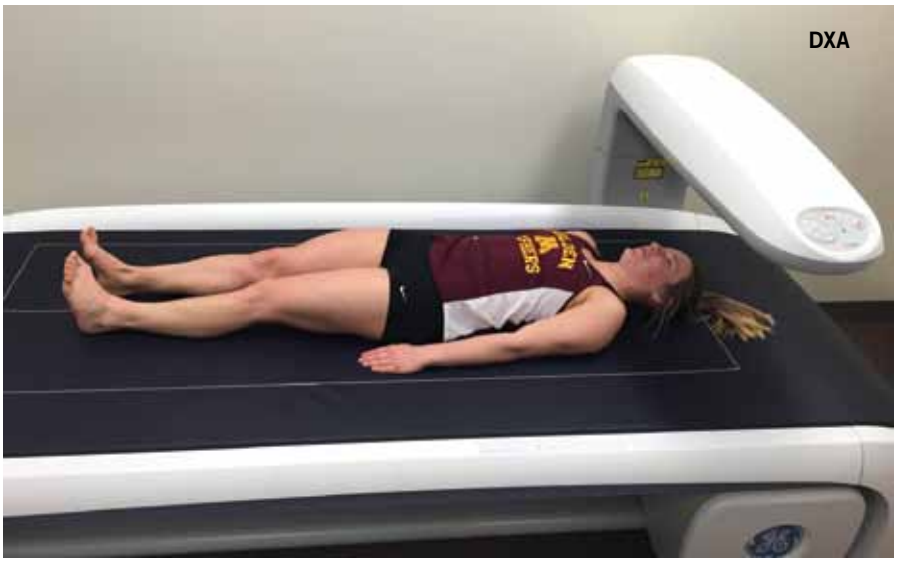
Anthro, athropometrics/skinfolds; UWW, underwater weighing

to estimate body composition it has to deal with these different types of tissues and fluids. The simplest, and typically the cheapest, methods to measure body composition usually use what is referred to as two-component model to estimate body composition. In other words, body composition methods that utilize a two-component model will group the total body mass into one of two components. The first component is the amount or mass of fat in the body and the second component is the amount of fat-free mass contained in the body. This second component (i.e., fat-free mass) places bone and muscle in the same component. Body composition methods based upon two-component models are associated with greater error in the measurement than methods based on multi-component models. The three-component models divides the fat-free mass component into bone mass component and a lean mass (i.e., muscle) component. Though bone does not typically account for a great amount of the total body mass of an individual the three-component model is more accurate than the two-component model. Unfortunately, the technology needed to measure three components accurately is expensive. Therefore, devices measuring three components often cost more than those devices that only measure two components.

TWO-COMPONENT MODEL METHODS

By far, the most common methods of estimating body composition fall into those methods that utilize a two-component model. The most often utilized two-component method of determining body composition is the measurement of skinfold thickness. (See skinfold photo) This rela-


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tively inexpensive field method uses a special caliper to make measures of skinfold thickness at a variety of sites around the body. These measures of subcutaneous fat are then inserted into an appropriate formula to calculate the body fat percentage. The formula chosen should be specific to the sex, age, and ethnicity of the individual. This method is dependent to some degree on the individual administering the test as well as the formula selected. The standard error of the skinfold technique is about 3-4 percent (Williams et al., 2013).

Another common two-component method of measuring body composition is hydrostatic weighing, (See Hydrostatic Weighing Photo) which is also known as underwater weighing. This method is based upon Archimedes' principal that an object immersed in water is acted upon by a buoyancy of the object and the amount of fluid the object, in this case a body, displaces. Because fat is less dense than either bone or muscles it weighs less in water. In this method an individual is weighed and then is placed inside of tank of water. After blowing out all of the air in his or her lungs and submerging his or her head below the water, he or she is weighed again in the water. After correcting for water temperature and subtracting the amount of air retained in the lungs after a forced expiration (i.e., residual lung volume), body volume equals the loss of weight in water. This method requires the investment of a water tank and special weighing system that makes the initial costs of the system rather expensive. At one time this method was considered the gold standard for measuring body composition, considering that the standard error of this technique is approximately 2-2.5 percent (Williams et al. 2013).

Another technique that uses the two-component model to estimate body composition is air displacement plethysmography. Similar to underwater weighing, however, instead of measuring the amount of water a subject displaces, this method uses air and calculates the volume of air that a subject displaces. This method requires a subject to sit in a sealed chamber designed to measure the amount of air they displace. It has a number of advantages over hydrostatic weighing such has not having to go underwater and it is simple to use. The system can be costly to purchase and it has a similar degree of standard error (2-3 percent) as hydrostatic weighing (Fosbol & Zerahn, 2015).

Another popular field method of estimating body composition is bioelectrical impedance analysis, which is based on the principle of resistance to an electrical current that is applied to the body. The greater the water content of the body the less the resistance and ultimately the greater the body density. Just like the skinfold thickness technique, the resistance is put into an equation to calculate percent fat. This equation is typically programmed into the machine and is often based upon age, sex and ethnicity. Measurement of body composition by bioelectrical impedance can be affected by a number of factors such as: a previous bout of exercise, body position, skin temperature, dietary intake, and hydration status (Fosbol & Zerahn, 2015). The accuracy of bioelectrical impedance is similar to that of the skinfold technique (3-4 percent), but does not require the technical skill of a skinfold user (Williams et al., 2013). (See BIA photo)

THREE-COMPONENT MODEL METHODS

As we mentioned, methods that estimate body composition using a three-component model are often more expensive and, until recently, mainly used in clinical setting. Recently, DXA (See DXA photo) has started to be used to estimate body composition in athletes and many professional and college teams have access to or own DXA devices. To determine the three components in the body, DXA uses two distinct low-energy X-Ray beams with short exposure and low radiation dosage to penetrate bone and soft tissue areas to a depth of approximately 30 cm. The subject lies supine on a table so the source and detector probes slowly pass across the body over a 12-minute period. Computer software reconstructs the attenuated X-Ray beams to produce an image of the underlying tissues and quantity bone mineral content, total body mass and lean tissue mass. The ability to measure bone density provides useful information regarding the thickness of bones, which is especially important for women and distance runners who may be at risk for osteoporosis. In addition, DXA may be used to assess regional fat deposit as well as abdominal visceral fat. The regional measurement of body composition allows

Table 4. Body Fat Percentages of Male and Female Distance, Marathon and Walkers

Category	Events	Caliber of Athlete	Sex	Number in Study	Method	Age (yrs)	Mass (kg)	Height (cm)	%fat	Reference
Long Distance	Unknown	Elite Finnish	Male	8	Anthro	26.2	66.2	177	8.4	Rusko et al., 1978
Long Distance	Steeplechase, 5,000m, 10,000m	1968 Olympics	Male	34	Anthro	25.3	59.8	171.9	8.7	de Garay et al., 1974
Long Distance	5,000m, 10,000m	U.S. Elite	Male	20	UWW	25.4	63.1	176.0	5.0	Pollock et al., 1977
Long Distance	Steeplechase, 5,000m, 10,000m	U.S. Elite	Male	32	UWW	21.7	68.7	181.4	9.9	Boileau et al., 1982
Long Distance	Unknown	U.S. Junior National	Female	28	UWW	13.1	42.8	157.1	16.5	Wilmore et al., 1974
Long Distance	Unknown	U.S. Elite	Female	15	Anthro	27.6	47.2	161.0	14.3	Graves et al., 1987
Long Distance	Unknown	U.S. National	Female	42	UWW	25.0	54.3	166.8	16.9	Wilmore et al., 1974
Marathon	Marathon	U.S. Elite	Male	8	UWW	27.4	62.1	176.8	4.3	Pollock et al., 1977
Marathon	Marathon	U.S. Olympic Trials	Male	114	Anthro	26.1	64.2	175.7	7.8	Costill et al., 1970
Marathon	Marathon	1968 Olympics	Male	20	Anthro	26.4	56.6	168.7	8.7	de Garay et al., 1974
Marathon	Marathon	Experienced Marathon runners	Female	13	Anthro	32.7	57.0	164.7	16.3	Christensen & Ruhling, 1983
Walkers	20km, 50km	1968 Olympics	Male	21	Anthro	27.1	62.9	173.2	9.4	de Garay et al., 1974

Anthro, athropometrics/skinfolds; UWW, underwater weighing

one to compare legs versus arms and right versus left side body composition. The method can estimate body fat with an error of less than 2 percent (Shephard, 1991).

MRI and computed tomography (CT) are also three component methods to determine body composition. However, both of these methods are limited by cost and/or radiation, which makes their use limited in the determination of body composition. These two methods of measuring body composition are expensive and in the case of CT involve higher levels of radiation. Typically, these two methods are only used in clinical or research settings.

ANALYSIS OF BODY COMPOSITION IN TRACK AND FIELD ATHLETES

So let's look at the body composition of various track and field athletes. It is important to remember that the athletes we are going to examine are elite and Olympic caliber athletes and therefore, one should be mindful in applying these values to high school and colligate athletes. Table 2 lists the height, weight and body fat percentages of male and female sprinters from junior to Olympic caliber athletes. On average, males sprinters are 177.5 cm tall (69.9 inches) and weigh on average 69.5 kg (153.2 pounds). However, it is important to remember that this is the average and there are exceptions. Usain Bolt, for example, is 195.6 cm (77 in) tall and weighs 85.7 kg (189 pounds). For male sprinters, the average percent fat is 9.1 percent. Female sprinters are 167.4 cm tall (65.9 in), weigh, on average, 57.0 kg (125.7 pounds), and have an average percent body fat of 13.7 percent. Table 2 demonstrates the wide range of body fat percentages from 10.7 percent for junior national women who may have not fully reached sexual maturation yet to 19.4 percent for collegiate women who may not be at the same level as Olympic female sprinters. This does not mean that all female sprinters need to be 13.7 percent to make the Olympics it just demonstrates the range of percent body fat that can exist in this population.

Today's middle distance runners typically require a unique blend of talents, requiring a high aerobic capacity like a distance runner, but also a well-developed anaerobic system like a sprinter. The body composition of these athletes is similar to that of their sprinter teammates. On average male middle distance runners are 179.8 cm (70.8 inches) tall, weigh 67.2 kg (148.1 pounds) and have an average percent body fat of 9.3 percent. Female middle distance runners are 165.1 cm (65.0 in) tall, weigh on average 52.9 kg (116.6 pounds) and an average percent body fat that is similar to female sprinters 14.1 percent. Again, Table 2 shows us the wide range of percent body fat in these athletes from 19.1 percent body fat in colligate middle distance runners to 10.9 percent body fat in Olympic female middle distance runners.

Long distance runners are often smaller than sprinters or middle distance runners, with male distance runners being 176.4 cm (69.4 inches) tall, weigh 64.4 kg (141.0

Table 5. Body Fat Percentages of Male and Female Throwers

Category	Events	Caliber of Athlete	Sex	Number in Study	Method	Age (yrs)	Mass (kg)	Height (cm)	%fat	Reference
Throwers	Shot put, Discus, javelin	U.S. Junior Olympic	Male	18	UWW	17.5	87.3	184.1	13.9	Thorland et al., 1981
Throwers	Shot put, Discus, Hammer	1968 Olympics	Male	14	Anthro	27.3	102.3	186.1	17.3	de Garay et al., 1974
Throwers	Shot put , Discus	Olympic	Male	12	UWW	27.6	108.6	187.1	16.5	Fahey et al., 1975
Throwers	Shot put, Discus, Javelin	U.S. Junior Olympic	Female	16	UWW	17.2	68.0	169.5	22.0	Thorland et al., 1981
Throwers	Shot put, Discus, Javelin	U.S. National	Female	9	UWW	18.8	80.8	173.9	27.0	Wilmore et al., 1974
Throwers	Shot put, Discus	1968 Olympics	Female	9	Anthro	19.9	73.5	170.9	26.1	de Garay et al., 1974
Throwers	Shot put, Discus, Javelin	Collegiate	Female	64	Anthro	21.3	74.4	167.5	26.5	Malina et al., 1971

Anthro, athropometrics/skinfolds; UWW, underwater weighing

Table 6. Body Fat Percentages of Male and Female Jumpers, Pole Vaulters and Multi-Event Athletes

Category	Events	Caliber of Athlete	Sex	Number in Study	Method	Age (yrs)	Mass (kg)	Height (cm)	%fat	Reference
Jumpers	High jump, Long jump, Pole vault	U.S. Junior Olympic	Male	16	UWW	17.6	69.2	181.7	8.5	Thorland et al., 1981
Jumpers	High jump, Long jump, Triple jump	1968 Olympics	Male	31	Anthro	23.5	73.2	182.8	9.4	de Garay et al., 1974
Jumpers	High jump, Long jump	U.S. Junior Olympic	Female	13	UWW	17.4	57.1	173.6	12.9	Thorland et al., 1981
Jumpers	High jump, Long jump	1968 Olympics	Female	12	Anthro	21.5	56.4	169.4	11.4	de Garay et al., 1974
Jumpers	High jump, Long jump	U.S. Junior Olympic	Female	13	UWW	17.4	57.1	173.6	12.9	Thorland et al., 1981
Pole Vault	Pole Vault	1968 Olympics	Male	6	Anthro	24.5	70.6	179.7	8.8	de Garay et al., 1974
Decathlon	Decathlon	1968 Olympics	Male	8	Anthro	25.1	77.5	181.3	10.3	de Garay et al., 1974
Heptathlon	Heptathletes	U.S. National	Female	19	DXA	25.5	67.3	175.0	15.0	Houtkooper et al., 2001
Pentathlon	Pentathletes	1968 Olympics	Female	11	Anthro	22.5	60.0	169.5	12.4	de Garay et al., 1974

Anthro, athropometrics/skinfolds; UWW, underwater weighing; DXA dual energy X-ray absorptiometry

pounds) and on average have a percent body fat of 8.0 percent. Females also tend to be smaller than their female sprinter counterparts being 161.6 cm (63.6 inches) tall and weight 48.1 kg (106.0 pounds). Surprisingly, they have a little more body fat (15.9 percent) than female sprinters. Male marathoners were 173.1 cm (68.1 in) tall, weighed 61.0 kg (134.5 pounds), and had an average percent body fat of 6.9 percent. Female marathoners were 164.7 cm (64.8 in) tall and weighed 57.0 kg (125.7 pounds). In regards to percent body fat, female marathoners were similar to female long distance runners at 16.3 percent. A racing walker, which is only a male Olympic sport, is similar in height (173.2 cm, 68.2 inches) and weight (62.9 kg, 134.3 pounds) to male marathoners. They did tend to have a little more body fat at 9.4 percent than male marathoners, but are still very lean.

Individuals who compete in the shot put, discus, javelin or hammer are often grouped together as throwers. This may be a little deceiving since an individual competing in the javelin will have a body type that is often much different than the athlete who competes in the shot put. Male throwers are 186.6 cm (73.5 inches)

tall and weight 105.4 kg (232.4 pounds). Female throwers are 170.8 cm (67.2 inches) tall and weight 76.2 kg (168 pounds). On average, male throwers had a body fat of 15.9 percent, while females had a percent body fat of 25.4 percent. It is important to remember, these data are mostly from the 1970s and 1980s. Both male and female throwers have gotten a lot taller and weigh a lot more today. So the weight and height of throwers today is probably much greater than what was reported in these studies, however the percent fat values may actually be similar to what was reported in these studies.

Table 6 contains body fat information on jumpers (i.e., high jump, long jump, and triple jump) as well as information on pole-vaulters, decathletes, and pentathletes\heptathletes. Male jumpers are 182.8 cm (72.0 inches) tall and weigh 73.2 kg (161.4 pounds). Male jumpers on average had a percent fat of 8.9 percent. Not too surprising, this amount of body fat was almost identical to the 9.1 percent body fat that sprinters had. Female jumpers are 169.7 cm (66.8 inches) tall and weigh 56.4 kg (124.3 pounds), generally having a percent body fat of 12.4 percent, which is identical to the level found in the two studies that examined female Olympic sprinters. Male pole-vaulters had a similar level of percent fat at 8.8 percent as jumpers and sprinters and were 179.7 cm (70.7 in) tall and weighed 70.6 kg (155.6 pounds). Though to date there are no studies on percent fat levels in female pole-vaulters, given that male jumpers, sprinters and pole vaulters are very similar in body composition it is reasonable to assume that female pole vaulters will have similar body fat levels as their jumping and sprinting counterparts. The multi-event athletes (i.e., decathletes, pentathletes\heptathletes) often require a unique blend of strength, speed and endurance. Therefore, it is not surprising to see that they have a little more body fat (10.3 percent in decathletes and 13.7 percent in pentathletes\heptathletes) than jumpers and sprinters. Male decathletes were 181.3 cm (71.4 inches) tall and weighed 77.5 kg (170.8 pounds). Female pentathletes\heptathletes were 172.3 cm (67.8 inches) tall and weighed 63.6 kg (140.2 pounds). As with throwers, there has, in all likelihood, been an increase in the size (i.e., height, weight) of both decathletes and pentathletes\heptathletes since these original studies were done.

CONCLUSION

In summary, while an athlete's body composition may help to optimize their performance in a given sport, it is important to remember that the purpose of this article is to act as a guide concerning the method of acquiring data on body composition and utilizing this data to alter training techniques in track and field athletes. It is our hope that this article will provide coaches and athletes with a reference, but in the end, it is important to remember that track and field athletes come in a variety of shapes and sizes and, ultimately, body compositions.

DISCLAIMER

The information provided in this article should not take the place of medical advice. Any specific questions should be directed toward appropriate health care provides (medical doctors, pharmacists, registered dieticians, etc.).

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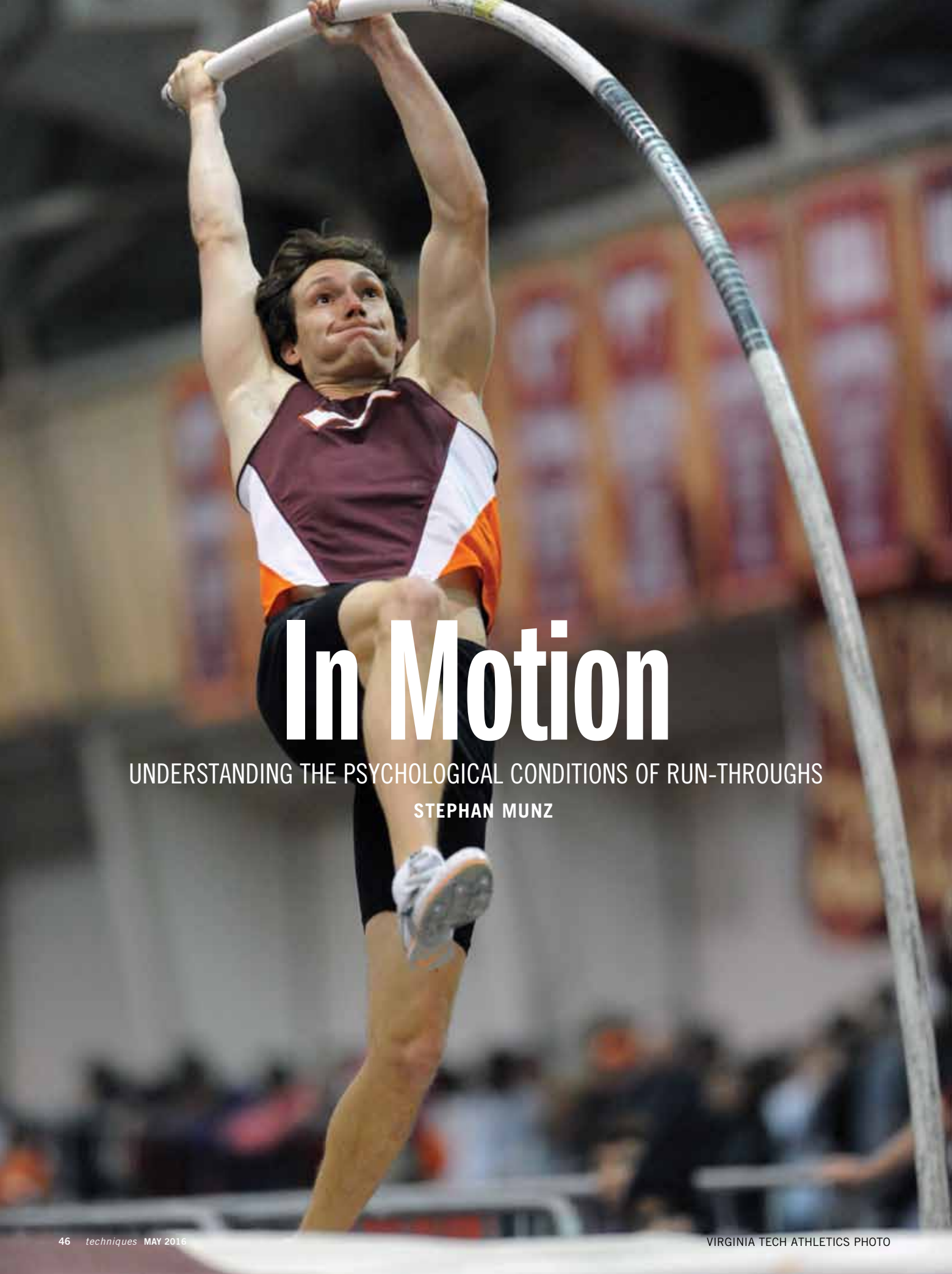
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In Motion

UNDERSTANDING THE PSYCHOLOGICAL CONDITIONS OF RUN-THROUGHS

STEPHAN MUNZ

VIRGINIA TECH ATHLETICS PHOTO

The pole vault is one of the most challenging and technical events in track and field (Orden, 1984). High physical demands such as speed, strength, agility, body control and coordination are coupled with equally important psychological aspects; all of which play an important role in the performance development of athletes. Often, the psychological demands of the event are so high a stagnation in the development of the vaulter can result, mainly when psychological states such as fear, lack of concentration or insufficient action control predominate. The run-through, an abrupt cessation of motion during the take-off phase, results in the inability of the vaulter to finish the jump. This can be a challenging situation for a vaulter to overcome. Depending on the degree of the problem, the run-through can affect the vaulter's development for several weeks, months or, in severe cases, it can end the vaulter's career. If athletes and coaches understood the underlying psychological principles of the run-through, and if coaches had a toolbox of exercises and guidelines of how to intervene if running through occurs, the vaulter's performance development would be improved. It is the goal of this series of two articles to analyze and define the underlying psychological conditions of running through behavior and to provide practical principles and strategies coaches can use to decrease the frequency and severity of the run-through in their athletes. The first section focuses on the psychological theories that can explain running through behavior. It will also present an interactional model to serve as a framework for coaches to locate possible problems. The second section presents practical applications and exercises coaches and athletes can incorporate in their training environments in order to decrease the likelihood of running through.

THE RUN-THROUGH

Coaches who have experience with athletes who run-through typically face the following scenario: An athlete stands at his or her approach mark. The vaulter prepares for the jump, uses chalk for his hands and grabs the pole. The vaulter seems nervous and checks external conditions such as wind and the pole over and over again. Finally, the vaulter extends the pole into the air and begins the approach. The vaulter accelerates, starts dropping the pole and initiates the plant motion three steps before the take-off. On the penultimate step, the vaulter puts his hands over his head and prepares for an active take-off step. However, instead of taking-off into the air and bending the pole, the vaulter drops the pole into the box and runs onto the pit despite the fact that the take-off spot was right on the mark and the conditions appeared perfect for the vaulter to finish the jump. Similar scenarios often happen repeatedly.

Running through can have different stages and patterns. Some vaulters suffer from running through for several practice sessions, others only run through during competitions and some may have running through problems for several months or years. The latter scenario often leads to stagnation or the end of a pole vaulter's career. Based on the analysis of the run-through frequency of German vaulters, Bender (2011) distinguishes between three different run-through types. There exists the vaulter that does not run-through at all, the vaulter who struggles with it occasionally or for inconsistent time periods, and the vaulter who has chronic running through problems over a long period of time. Bender also discovered that there are no significant differences among the age and gender of athletes when it comes to the frequency and severity of running through (Bender, 2011).

A HOLISTIC MODEL OF THE RUN-THROUGH

There are many psychological processes that occur between the intentional process and the actional process. Nolting and Paulus (1999) developed a behavioral model that helps to understand how intentional behaviors are influenced. The model explains how developmental conditions, personal dispositions, current internal processes and situational conditions affect and influence certain behaviors. Bender (2011) used this model to create a holistic picture of the factors influencing the run-through. Figure 3 shows an adaptation of Bender`s model based on the principles of Nolting and Paulus. This model can serve coaches as a framework to identify possible variables that cause running through behavior.

The model consists of three influencing components (developmental processes, physical and psychological dispositions, and situational conditions) that have an active impact on the internal cognitive and emotional processes of the athlete. The evaluation and results of these cognitive and emotional processes are the key components of how vaulters feel and evaluate their situation, resulting in a successful or unsuccessful execution of the take-off. The model can also serve as an orientation for other jumps coaches (long jump, triple jump, and high jump) if chocking occurs during the execution of the jump.

DEVELOPMENTAL PROCESSES AND PSYCHOLOGICAL DISPOSITIONS

The level of developmental processes, such as prior experiences, has a positive or negative effect on the personal disposition of the vaulter. These experiences

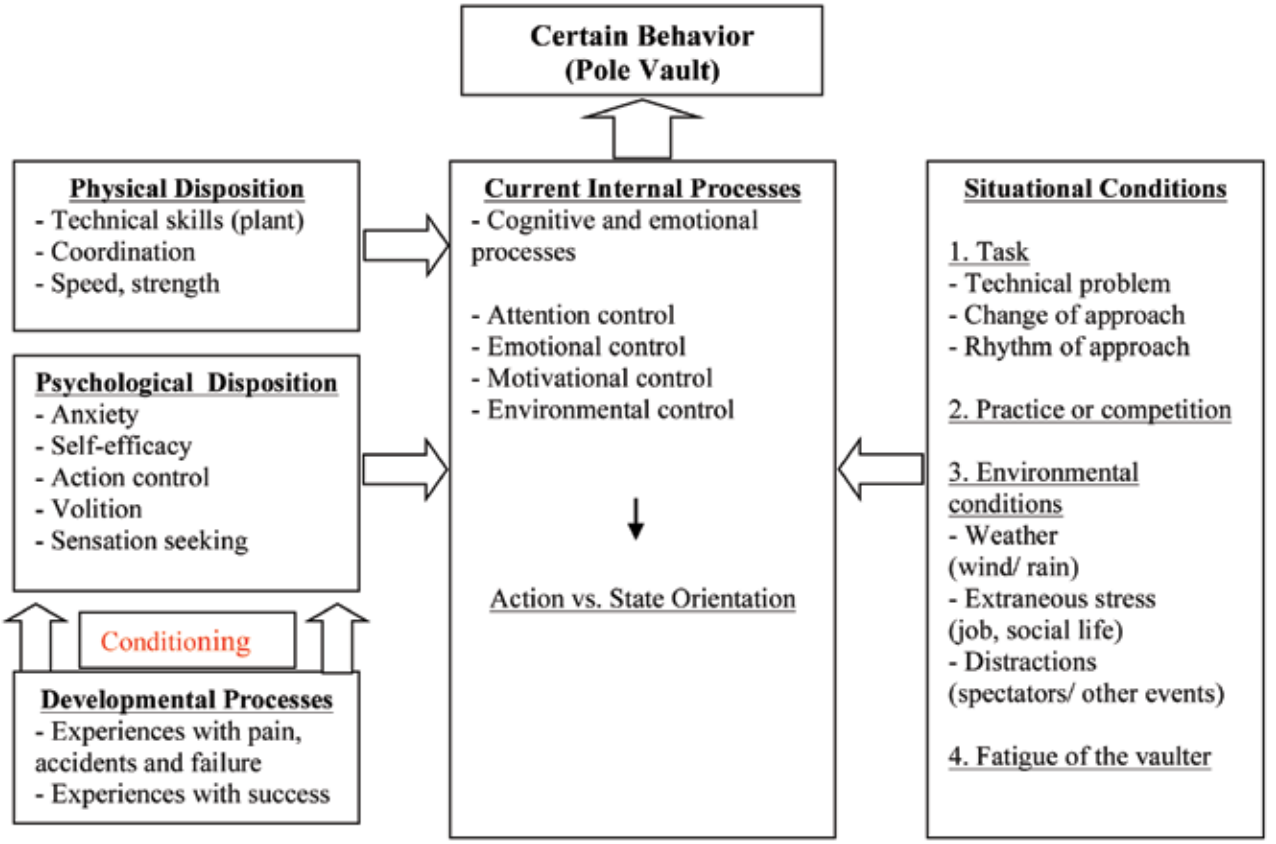


Figure 3: Interaction-theoretical model of factors that influence the run-through. Adapted from Handlungskontrolle und Angst im Stabhochsprung (p.166), by Ralf Bender, 2011, Aachen, Meyer &Meyer Verlag.

can include accidents, pole breaks or periods of running through, but may also be moments of success, stability in practice or feelings of excitement. Such encounters work to shape the manifestation of personal dispositions such as anxiety, self-efficacy and action control. The disposition for anxiety in particular can cause a conditioning process to occur. The following section analyzes this conditioning process. Additionally, the article will focus on the aforementioned components of anxiety, self-efficacy, action control and volition. In my opinion, these dispositions are the most complex and important ones concerning the causes of running through.

The consideration of psychological dispositions and traits in relation to the run-through assumes the fundamental units of personality are relatively stable. They influence the person to act in a certain way based on the level and degree of the disposition and are consistent across a variety of situations. For example, if an athlete`s disposition of competitiveness is high, it is more likely that he or she will play hard and put forth high effort, regardless of the situation or score (Weinberg & Gould, 2011). However, these dispositions may change if an athlete experiences certain scenarios repeatedly. If vaulters experience multiple pole breaks or unsuccessful jumps, it will affect their degree of anxiety, self-efficacy, action control and volition in future situations.

Anxiety. In his study about psychological aspects of the pole vault, current German pole vault coach Joern Elberding (1998) asked thirteen German pole vaulters about the most critical factors that can lead to running through behavior. Interviews revealed that perceptions of danger and feelings of anxiety were the top components. This stands in agreement with the study of Bender (2011), who identified anxiety as the most important factor for running through behavior. Unlike state anxiety, a temporary, ever-changing emotional state of perceived feelings of apprehension and tension, trait anxiety is a behavioral disposition to perceive certain circumstances as threatening that objectively may not be dangerous, and to then respond with disproportionate state anxiety (Spielberger, 1966). This means that vaulters with high trait anxiety are more likely to experience apprehension and tension when they have to face challenging situations in the vault. Based on my personal experience as a former pole vaulter and current volunteer assistant coach, vaulters seem more likely to run-through if they face a last attempt scenario, difficult extraneous conditions, or if they go up a pole.

How does a vaulter develop a high trait anxiety that can lead to running through? In some cases, the work of Ivan Pavlov, the Russian physiologist whose

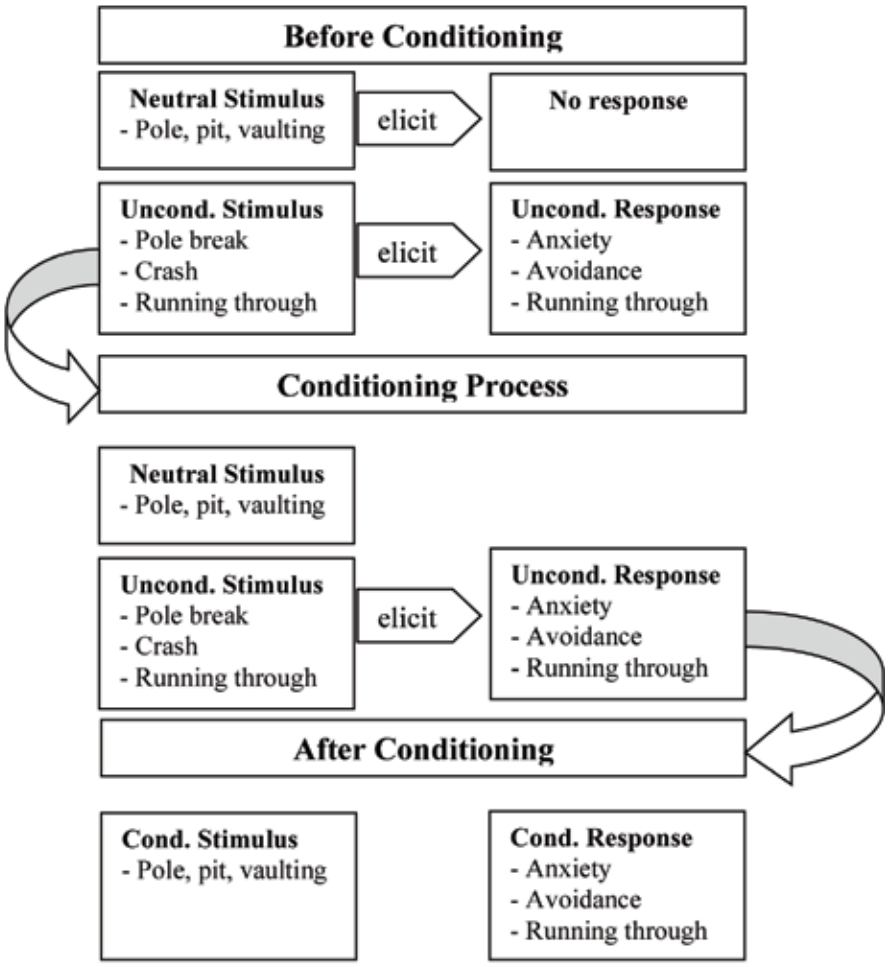


Figure 4: Conditioning process of past trauma in the pole vault. Adapted from Applying Educational Psychology in Coaching Athletes (p.93), by Jeffrey Huber, 2013, Champaign, Human Kinetics.

name has become a synonym for classical (respondent) conditioning, can provide an answer to this question. The following figure illustrates how pole breaks, failure, and crashes can condition the neutral stimulus of pole vaulting into a conditioned stimulus that results in anxiety and running through behavior. Neutral stimuli do not show any response before the conditioning process starts. However, unconditioned stimuli such as pole breaks, crashes or other negative experiences can elicit an unconditioned response. This process can lead to a conditioning process in which the neutral stimulus of the pole, pit, or the pole vault motion becomes a conditioned stimulus that elicits a conditioned response such as fear, dislike, or running through behavior. As a result, when this conditioning process comes into play, the vaulter will have a higher anxiety level when faced with the task of vaulting. The athlete can experience anxiety simply by thinking about the execution of the pole vault movement, or by looking at a pole or pole vault pit. Vaulters do not have to consciously think about their experiences with pole vaulting; they will simply react automatically when presented with pole vault stimuli.

Consequently, it is crucial for coaches to ensure that athletes practice in a safe environment to avoid traumatic injuries and to sequentially master skills before progressing to more difficult tasks (Huber, 2013). The second paper of this two articles series will explain how coaches can decondition anxiety with a variety of exercises.

It is important to note that the conditioning process in response to accidents or negative experiences can elicit running through behavior. However, the conditioning process is not the only reason why anxiety and avoidance behavior can occur. Other cognitive processes and theories can come into play as well, such as the conflict model of Dollard and Miller (1950), Epstein`s theory of anxiety inhibition (1967), or Lazarus`s theory of cognitive anxiety (1966). These theories, however, are beyond the scope of this paper.

Self-efficacy. The influence of one's perception about personal skills and capabilities is equally important to the conditioning of anxiety when it comes to considering the running through behavior. If vaulters are confident about their skills, technical knowledge, speed and strength, it is more likely that they can overcome difficult scenarios and states of anxiety. A high level of confidence can lead to a more evolved perception and interpretation of bad experiences (Bandura, 1993, 1997). Psychologist Albert Bandura brought together the concepts of confidence and expectations to create a clear model of self-efficacy. According to Bandura (1997) self-efficacy is "the belief in one`s capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). This means that if someone has requisite skills and sufficient motivation, then the major determinant of the individual`s performance is self-efficacy. Self-efficacy also affects choices, level of effort, and persistence of an athlete (Weinberg & Gould, 2011). For example, I believe that a vaulter with high self-efficacy will have fewer problems completing a jump in a meet when the extraneous conditions such as wind and other factors are not optimal. In addition, vaulters can overcome prior failure and bad experiences much easier, because they are aware of their skills and capabilities. The following model displays the factors that can influence a vaulter's self-efficacy.

Volition and Action Control. It is interesting that some athletes are able to maintain their actions and achieve their goals, whereas others are incapable of transforming their motivation into action or cannot remain focused (Elbe, Szymanski, & Beckmann, 2005). For example, in the pole vault there may be two vaulters with the same level of motivation who are both willing to engage in the execution of the pole vault motion. However, one of the vaulters has the toughness and will to

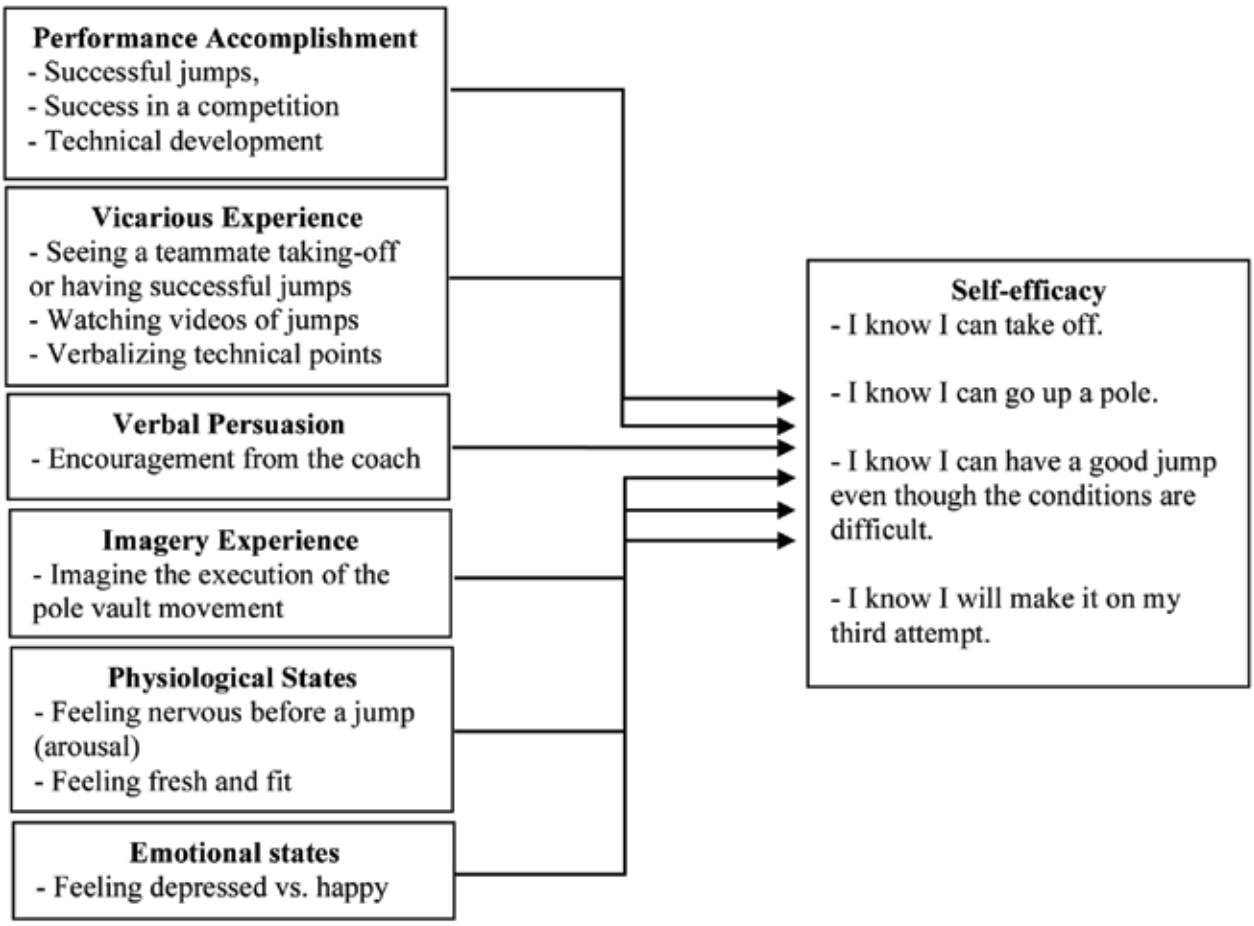


Figure 5: Influential factors of self-efficacy in the pole vault. Adapted from Self-efficacy as a cognitive mediator of athletic performance by D. Feltz, 1984, Cognitive sport psychology, edited by W. Straub and J. Williams, Lansing NY, Sport Science Association.

execute the movement under difficult conditions and the other vaulter runs-through. Kuhl (1987) makes the point that motivation leads to the decision to act. However, if an individual is already engaged, volitional action processes determine whether the intention will be executed or not. Volition is a construct from motivational psychology that describes self-regulatory processes that can protect the execution of an intention from extraneous variables. It is commonly referred as "the will" of a person to engage in a behavior. It deals with the processes that allow for the execution of an action despite internal and external resistance and the maintenance of the action until a specific goal is reached (Kuhl, 1983). The vaulter with high volition is less distracted and remains confident and positive during the execution of the movement even during harsh circumstances. Numerous studies have found that athletes with higher volitional skills are more likely to have better athletic achievements (Beckmann, 1999; Beckmann & Kazén, 1994).

The underlying system of volition consists of several processes that are responsible for protecting and coordinating the intention of a specific action. These strategies can be seen as action control strategies and include attention control, motivation control, emotion control, failure control and limitation of information processing. Figure 6 illustrates the action control strategies and explains its functioning in the pole vault. At this point, it is important to note that there is a smooth transition between the psychological disposition or trait of an athlete and the current internal and emotional processes (See Figure 3). The processes of the action control are the current emotional and cognitive processes that take place in a vaulter's mind before or during the execution of a jump. The quality and evaluation of these processes determine whether the execution of the movement can be protected or not. In other words, the evaluation of the action control is a factor in whether or not the athlete runs through.

There can be two outcomes based on the evaluation and result of the internal processes of the action control strategies. Based on Kuhl's (1983, 1985, 1987,

1996) interpretation of action-control strategies, one could argue that a vaulter is either in a state or action orientation. If the vaulter is in a state condition, he or she is likely to run-through. The vaulter loses control of the internal processes and evaluations and begins to fixate on the conditions of the current situation and consequences or situations of the past. This results in the vaulter expending energy and cognitive load on different scenarios and hypothetical situations. In this case, the vaulter will begin to shut down. For example, in the condition of state orientation, the vaulter would only think about the consequences of a bad jump or a run-through. The coordination of the action control strategies fall apart and the vaulter would continue running through. On the other hand, a vaulter in the state of action orientation is confident and does not think about negative consequences. He or she can protect the intention and execute the action in an efficient way. In addition, the vaulter is capable of making adaptations during the vault due to the fact that he or she did not waste cognitive load on second thoughts or doubts. As a result, the vaulter can focus on the correct execution of the pole vault motion.

As a final result, one can say that the developmental processes, personal disposition (traits), and current internal processes (states) are all interrelated when it comes to running through behavior. Depending on the individual and the situation, the importance of each disposition or process can play a different role. Running through behavior is such a complex structure that it is impossible to create a holistic picture that is always applicable. There are also several other theories about anxiety, self-efficacy, motivation, stress, or volition that could provide explanations of running-through behavior. Another theoretical approach could be the sensation-seeking concept that is mentioned in Figure 3 under psychological dispositions. The concept attempts to explain how people with a high sensation-seeking tendency are more likely to engage in risky behaviors (Zuckermann, 1994). It can be assumed that vaulters with a high sensation-seeking trait are more action oriented when it comes to the execution of the pole vault movement, which is a risky activity itself.

PHYSICAL AND TECHNICAL DISPOSITION

Physical dispositions play an equally important role in regards to the running through behavior. First and foremost, the technical skills are critical. If a vaulter does not have a good approach rhythm and if the approach is not automated and accurate, the vaulter will be inconsistent and the take-off spot unstable. This can lead to insecurity, and the vaulter can lose the rhythm and feeling for the approach and take-off movement. In addition, the plant motion must be automated and technically correct. If the plant is too late and the arms are not accurately above the head after the penultimate step, the vaulter cannot engage in a proper and controlled take off-motion. A good understanding of the mechanics of the pole vault is fundamental to understanding causes and effects of running through, due to the complexity of the pole vault movement. However, a detailed technical and biomechanical analysis of the approach, plant, and take-off motion is beyond the scope of the analysis in this piece.

SITUATIONAL CONDITIONS



It should be obvious that difficult situational conditions, such as environment, fatigue, and task play an important role in running through behavior. Based on personal experience I believe that if vaulters are already unstable, disoriented or anxious, unfavorable situational conditions are the final triggering component that can cause a run-through. The first influential variable can be the task that vaulters have to execute. For instance, pole vaulters may have technical problems, or the coach may give them too many cues to focus on. If vaulters have to actively think and reflect about too many changes they want to make during the jump an overload of the cognitive capacity can occur. This can cause a shutdown of the movement, especially if the technical problems are based on the rhythm of the approach, plant, or take-off motion.

Secondly, I believe that there are large discrepancies between practice and competition scenarios in terms of running through. Both scenarios can influence the run-through in a positive or negative way. For example, it is possible that vaulters have run-through problems in practice due to a lack of motivation or engagement, but vaulters do not run through in a competition because of the increased adrenaline and pressure of the meet. They are more focused and more consistent and energetic in terms of the execution of the movement. It can also be the other way around. Due to anxiety, stress, or nervousness vaulters can have severe run through issues during a competition, but none during practice. A competitive situation affiliated with stress or other extraneous variables such as loud noises or simultaneous events can reduce the concentration and attention control of vaulters. They are unable to focus on the execution of the movement and they cannot protect the intention of taking-off (see Figure 3: Current Internal Processes).

Thirdly, environmental conditions can also play an important role in terms of situational conditions. A head or crosswind can make it extremely difficult for vaulters to execute the plant and take-off motion. In addition, it can be assumed that vaulters feel less confident and secure if they start the approach into a head wind. Vaulters can feel less powerful and develop second thoughts during the approach. If vaulters cannot control and suppress these thoughts with their action control strategies, it is likely that they become distracted during the approach and run through. However, further research needs to be conducted to support that thesis.

An additional environmental condition can be unrelated stress in the vaulter's personal life. Social problems or stress in school or work can have a negative impact on the energy level and commitment of the vaulter. The vaulter is more preoccupied and less motivated due to the emotional burden. It can be assumed that the vaulter has less energy, which results in a reduced concentration level. The vaulter has more difficulties in protecting the intention of executing the movement.

Fatigue of the vaulter is another situational condition. The pole vault is a challenging and exhausting event. Specifically at the end of a practice session or competition, vaulters experience the most tiredness and fatigue. Often times, a vaulter is on the largest pole at the end of practice or competition. This requires maximum concentration, energy and volition. However, the vaulter is less alert at this time due to the immense physical and mental stress. As a result, it can be possible that the vaulter loses the energy and commitment to finish the jump, resulting in running through.

After presenting several variables that can influence running through, the next article will present guidelines and principles that can be applied to reduce the likelihood of the run-through. The holistic picture that was presented above should serve as an overview for coaches and athletes to evaluate and identify their own situation if they deal with continuous running through. The model can serve as an orientation and framework so that coaches and athletes may draw the right conclusions and intervene with the appropriate strategies.

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Action Control Strategy	Explanation and Functionality of the Strategies
Attention Control	Concentration on intention relevant stimuli and variables Example: The vaulter is able to only focus on variables that help him to execute the motion in a successful way. The vaulter can block out extraneous and disturbing stimuli that are irrelevant for the execution of the movement such as wind, noise or other events.
Motivation Control	Focus on pleasant stimuli of the goal. Devaluate competing goals of the main action Example: The vaulter focuses on the pleasant feeling of having a successful jump and values the achievement of this goal. The vaulter devaluates the unpleasant feeling of not exposing himself to a difficult situation. "Despite the difficult conditions I still want to experience a successful jump."
Emotional Control	Put oneself in a mood that is beneficial for the execution of the intention Example: The vaulter is positive and full of energy. He is aware of his skills and abilities. He or she can suppress the feeling of doubt, anxiety and fear.
Failure control	Failure is used and seen as a learning process. Emotional consequences of failure are used as a motivational opportunity to mobilize more energy for future actions Example: The vaulter experiences failure due to a bad jump or run-through. He or she uses this bad experience to learn from the mistakes. The vaulter assesses the failure as an opportunity of growth. He or she stays positive and takes the necessary actions to make it better the next time.
Environmental Control	Avoidance or removal of disturbing stimuli and variables Example: The vaulter is aware of what it takes to execute the movement. He or she can analyze the environment and detect disturbing variables that could hinder the execution. For example, a different training squad plays loud music during the vault session and the vaulter cannot concentrate in a sufficient way. An experienced vaulter knows that this inhibits his or her concentration and avoids or removes the negative stimulus from the environment.

Figure 6: Action-control strategies and its functioning in the pole vault (on the basis of Kuhl 1983, 1985,1987, 1996). Adapted from "Handlungskontrolle und Angst im Stabhochsprung" by Ralf Bender, 2011, Aachen, Meyer & Meyer Verlag.

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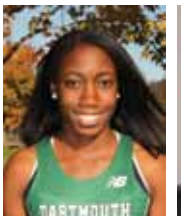
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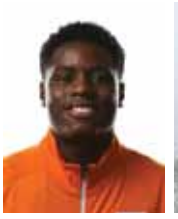
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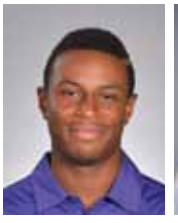
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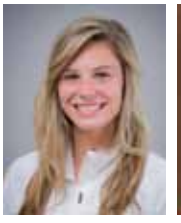
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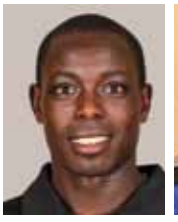
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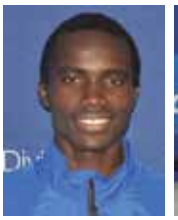
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Claflin
Men's Head COY



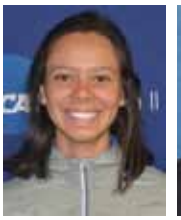
Soyini Thompson
Alabama-Huntsville
Women's Assistant COY
Men's Assistant COY



Ayana Walker
Shorter
Women's Track AOY



Alfred Chelanga
Shorter
Men's Track AOY



Christina Aldana
Shorter
Women's Field AOY



Alex May
Alabama-Huntsville
Men's Field AOY

SOUTH CENTRAL REGION



James Reid
Angelo State
Women's Head COY



Ross Smithey
Texas A&M-Commerce
Men's Head COY



Yuriy Litvinski
Angelo State
Women's Assistant COY



Chris Siemers
Colorado Mines
Men's Assistant COY



Shanna Thomas
New Mexico Highlands
Women's Track AOY



Sydney Gidabuday
Adams State
Men's Track AOY



Salcia Slack
New Mexico Highlands
Women's Field AOY



Jeron Robinson
Texas A&M-Kingsville
Men's Field AOY

SOUTHEAST REGION



Jim Vahrenkamp
Queens
Women's Head COY



Joseph Wassink
Limestone
Men's Head COY



Tsehaye Baney
Queens
Women's Assistant COY



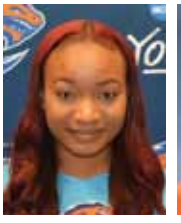
Tyler Stepp
Carson-Newman
Men's Assistant COY



Nikia Squire
Queens
Women's Track AOY



Marquett Simmons Jr.
Limestone
Men's Track AOY



Jessica Matthews
Clayton State
Women's Field AOY



Tanner Stepp
Carson-Newman
Men's Field AOY

WEST REGION



Michael Friess
Alaska Anchorage
Women's Head COY



Kevin LaSure
Academy of Art
Men's Head COY



Audra Smith
Seattle Pacific
Women's Assistant COY



Tom Dickson
Simon Fraser
Men's Assistant COY



Joyce Chelimo
Alaska Anchorage
Women's Track AOY



Mobolade Ajomale
Academy of Art
Men's Track AOY



Karolin Anders
Alaska Anchorage
Women's Field AOY



Payton Lewis
Northwest Nazarene
Men's Field AOY

DIVISION III 2016 USTFCCCA REGIONAL INDOOR COACHES & ATHLETES OF THE YEAR

ATLANTIC REGION



Angelo Posillico
SUNY Oneonta
Women's Head COY



Steve Patrick
SUNY Cortland
Men's Head COY



Matthew Scheffler
Ithaca
Women's Assistant COY



Jay Petsch
Rochester
Men's Assistant COY



Amy Regan
Stevens
Women's Track AOY



Nicodemus Gambill
Utica
Men's Track AOY



Katherine Pitman
Ithaca
Women's Field AOY



Luis Rivera
Nazareth
Men's Field AOY

CENTRAL REGION



Ted Bulling
Nebraska Wesleyan
Women's Head COY



Steve Mathre
St. Thomas
Men's Head COY



Rich Maleniak
St. Thomas
Women's Assistant COY



Todd Bouchie
St. Scholastica
Men's Assistant COY



Emily Gapinski
St. Thomas
Women's Track AOY



Paul Escher
St. Olaf
Men's Track AOY



Samantha Dolezal
Nebraska Wesleyan
Women's Field AOY



Logan Mulford
Central
Men's Field AOY

GREAT LAKES REGION



Kris Boey
Ohio Wesleyan
Women's Head COY



Kevin Lucas
Mount Union
Men's Head COY



Julius Higginbotham
Wooster
Women's Assistant COY



Tyler Mettille
Mount Union
Men's Assistant COY



Emily Richards
Ohio Northern
Women's Track AOY



Matt Molinaro
Ohio Northern
Men's Track AOY



Kim Gallavan
Baldwin Wallace
Women's Field AOY



Tyler Burdorff
Baldwin Wallace
Men's Field AOY

MIDEAST REGION



Bobby Van Allen
Johns Hopkins
Women's Head COY



Stephen Kimes
Wesley
Men's Head COY



Bradi Rhoades
Westminster
Women's Assistant COY



Jim Townsend
Johns Hopkins
Men's Assistant COY



Ashley West
Susquehanna
Women's Track AOY



Luke Campbell
Salisbury
Men's Track AOY



Olivia Jendrzejewski
Lebanon Valley
Women's Field AOY



Andrew Bartnett
Johns Hopkins
Men's Field AOY

2016 USTFCCCA REGIONAL DIVISION III
INDOOR COACHES & ATHLETES OF THE YEAR

MIDWEST REGION



Chris Schumacher
Illinois Wesleyan
Women's Head COY



Roger Haynes
Monmouth
Men's Head COY



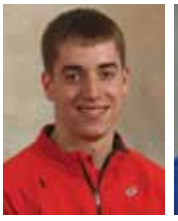
Mahesh Narayanan
North Central
Women's Assistant COY



Dan Schwamberger
UW-Eau Claire
Men's Assistant COY



Nia Joiner
Illinois Wesleyan
Women's Track AOY



Ethan Reschke
Monmouth
Men's Track AOY



Amber Williams
UW-Platteville
Women's Field AOY



Alex Mess
UW-Eau Claire
Men's Field AOY

NEW ENGLAND REGION



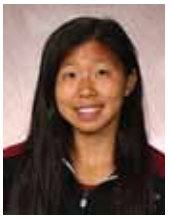
Halston Taylor
MIT
Women's Head COY
Men's Head COY



Sarah Lagasse
Williams
Women's Assistant COY



Michael Schmidt
Tufts
Men's Assistant COY



Maryann Gong
MIT
Women's Track AOY



Mitchell Black
Tufts
Men's Track AOY



Cimran Virdi
MIT
Women's Field AOY



Arinze Okeke
MIT
Men's Field AOY

SOUTH/SOUTHEAST REGION



John Curtin
Emory
Women's Head COY



Tyler Wingard
Christopher Newport
Men's Head COY



Denver Davis
Bridgewater
Women's Assistant COY



Matthew Barreau
Christopher Newport
Men's Assistant COY



Amber Celen
Bridgewater
Women's Track AOY



Daniel Pietsch
Emory
Men's Track AOY



Dana Lee
Washington and Lee
Women's Field AOY



Renn Eason
Rhodes
Men's Field AOY

WEST REGION



Toby Schwarz
Whitworth
Women's Head COY



Mike Orechia
Puget Sound
Men's Head COY



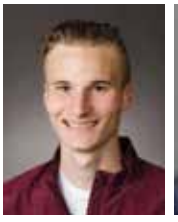
Shannon Winant
Whitworth
Women's Assistant COY



Tramaine Payne
Linfield
Men's Assistant COY



Katie McKay
Whitworth
Women's Track AOY



Geremia Lizier-Zmudzinski
Puget Sound
Men's Track AOY



Asia Greene
George Fox
Women's Field AOY



Corey Burt
Whitworth
Men's Field AOY

NJCAA 2016 USTFCCCA REGIONAL INDOOR COACHES & ATHLETES OF THE YEAR

ATLANTIC



Lesleigh Hogg
Monroe Community College
Women's Head COY
Men's Head COY



Shirvon Greene
Monroe Community College
Women's Assistant COY
Men's Assistant COY



Susan Ejore
Monroe Community College
Women's Track AOY



Jaymes Dennison
Monroe Community College
Men's Track AOY



Breaisha Morton
Monroe Community College
Women's Field AOY



Torry Miller
Richard Bland Community College
Men's Field AOY

CENTRAL



Craig Perry
Coffeyville Community College
Women's Head COY



Ryan Turner
Butler Community College
Men's Head COY



Tony Davis
Barton County Community College
Women's Assistant COY



Greg Franklin
Butler Community College
Men's Assistant COY



Tasha Frazier
Barton County Community College
Women's Track AOY



Quintaveon Poole
Butler Community College
Men's Track AOY



Angelica Collins
Coffeyville Community College
Women's Field AOY



Landon Cuskelly
Butler Community College
Men's Field AOY

MIDWEST



Denny Myers
Iowa Central Community College
Women's Head COY
Men's Head COY



Brad Foote
Iowa Central Community College
Women's Assistant COY



Nigel Bigbee
Iowa Central Community College
Men's Assistant COY



Danielle Riggins
Iowa Central Community College
Women's Track AOY



Sylvester Barus
Iowa Western Community College
Men's Track AOY



Janeah Stewart
Iowa Central Community College
Women's Field AOY



Jacob Barents
Iowa Western Community College
Men's Field AOY

WEST



Keith Blackwill
New Mexico Junior College
Women's Head COY



Chris Beene
South Plains Community College
Men's Head COY



Trinity Williams
Western Texas College
Women's Assistant COY

Not Pictured

Brian Makupson
Gillette College
Men's Assistant COY



Medinah Spencer
South Plains Community College
Women's Track AOY



Festus Lagat
Gillette College
Men's Track AOY



Portious Warren
Central Arizona Community College
Women's Field AOY



Fabian Edoki
South Plains Community College
Men's Field AOY

2016 USTFCCCA REGIONAL INDOOR COACHES & ATHLETES OF THE YEAR

NAIA

GREAT LAKES



Doug Edgar
Indiana Tech
Women's Head COY
Men's Head COY



Nick Sharin
Indiana Tech
Women's Assistant COY



Austin Roark
Indiana Tech
Men's Assistant COY



Sarah Dunmore
Indiana Tech
Women's Track AOY



Harris Edwards III
Indiana Tech
Men's Track AOY



Tia Holmes
Indiana Tech
Women's Field AOY



Alain Dixon
Indiana Tech
Men's Field AOY

MIDWEST



Ed Fye
Doane
Women's Head COY
Men's Head COY



Ed McLaughlin
Concordia
Women's Assistant COY
Men's Assistant COY



Kim Wood
Concordia
Women's Track AOY



Sam Wensink
Dordt
Men's Track AOY



Paige Hervert
Doane
Women's Field AOY



Zach Lurz
Concordia
Men's Field AOY

SOUTH



David Andrews
Webber International
Women's Head COY



Ryan McKenzie
William Carey
Women's Assistant COY



Sam Roberts
Tennessee Wesleyan
Men's Assistant COY



Hannah Segrave
Milligan
Women's Track AOY



Jordan Clarke
Webber International
Men's Track AOY



Jonina Brinson
Mobile
Women's Field AOY



Tobias Durham
Warner
Men's Field AOY

SOUTH CENTRAL



Cole Davis
Friends
Women's Head COY



Damian Smithhisler
Friends
Men's Head COY



Remuro Henry
Wayland Baptist
Women's Assistant COY



Dennis Smithhisler
Friends
Men's Assistant COY



Katherine Dillard
Benedictine
Women's Track AOY



Jacob Clark
Friends
Men's Track AOY



Kaitlyn Keck
Friends
Women's Field AOY



Trey Bellows
Friends
Men's Field AOY

WEST



Pat McCurry
College of Idaho
Women's Head COY



Russell Smelley
Westmont
Men's Head COY



Joshua Priester
Westmont
Women's Assistant COY



Jeff Hoskisson
Eastern Oregon
Men's Assistant COY



Leah Esposito
Carroll
Women's Track AOY



Sam Atkin
Lewis-Clark State
Men's Track AOY



Rebeccah Collier
Westmont
Women's Field AOY



Eric England
Eastern Oregon
Men's Field AOY

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- Training Design for Track & Field
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- An Overview of the Throwing Events
- An Overview of the Endurance Events
- Training Design for the Endurance Events

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