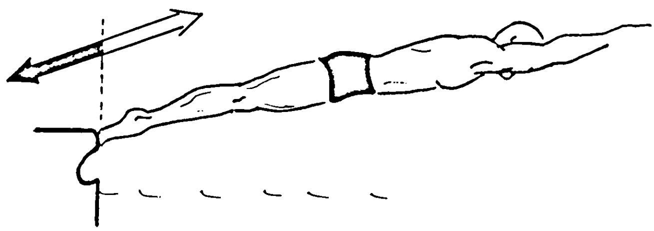
1 Simple Mechanics Related to Diving

Newton's Third Law of Motion

A good understanding of diving mechanics requires a good understanding of Newton's "third law." A great deal of what happens in the air, and indeed before the diver leaves the board, depends on it. The law states that for every action there is an equal and opposite reaction. This means that when a force is applied in one direction against an object, the object returns the force equally and in the opposite direction. (1.1)

When a rocket thrusts hot gases back, the gases push back against the rocket equally and in the opposite direction, resulting in a lifting movement. When a swimmer pushes back against the water, the water pushes back against the swimmer's arm, moving him ahead. A diver who pushes down against the surface of the diving board is being pushed up by the board; if he pushes backward, the board pushes forward against his feet (see Chapter 11); if he pushes sideways, the board pushes back the other way. This is how both twist and spin are started from the board.

1.1
At the start of a race a swimmer pushes *back* against the wall, which in turn pushes his body forward for the dive.



A Body Free in Space: After a diver is in the air, if he moves one part of his body in one direction, the rest of his body reacts by moving in the opposite direction. Should he move his arms to the right across his chest, his body will twist to the left and not to the right, as commonly believed. (1.2) From a pike position, if he moves his legs out of the pike, his upper body will move away from the legs, and his legs will move away from the body as well. (1.3)

Center of Gravity

The center of gravity is an imaginary point around which the body weight is equally distributed. In spinning dives a diver always spins around his center of gravity. It can fall outside of the body proper. When a diver bends over into a pike position, his center of gravity can be somewhere in the space between his upper body and his legs. (1.4)

Center of gravity is really the point around which the body is in equilibrium.

Linear and Angular Motion

Linear motion refers to movement in a straight line. A train moving along a straight track exhibits linear motion. When it goes around a curve, it has angular motion. When a diver spins in a one-and-a-half somersault or twists in a double twister, he exhibits angular motion.

Angular Velocity

Angular velocity refers to the speed of the spin, the revolutions per minute. The angular velocity of a spinning body may be changed because it depends on the moment of inertia.

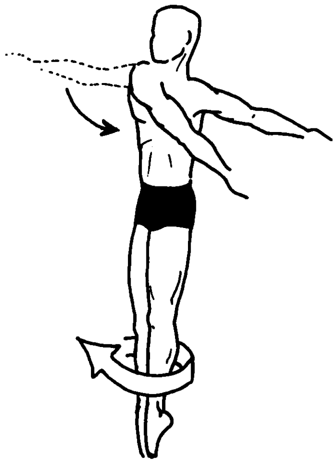
Moment of Inertia

Moment of inertia is a property of bodies having rotational motion around an axis. It is the mass times the square of the distance of the center of that mass to the axis of rotation. This distance is referred to as the *radius of gyration*. Because the mass (or weight)[1] of the various body parts remains constant in diving, the significant factor in determining speed of the spin is the radius of gyration. When a diver tucks his body into a ball, he shortens the radius of gyration, and the moment of inertia decreases. This speeds up the spin.

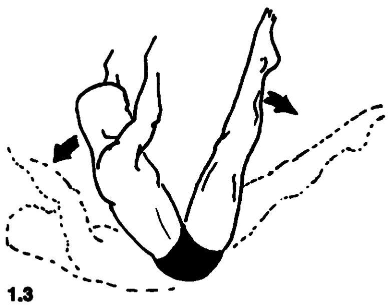
Angular Momentum

For our purposes angular momentum may be referred to as the *amount* of spin and is expressed as the moment of inertia multiplied by the angular velocity. It is not the same as the speed of the spin.

If a diver turns as he leaves the board, he has angular momentum. He cannot get it once he is in the air. The *amount* of spin must be determined from the diving board.



1.2



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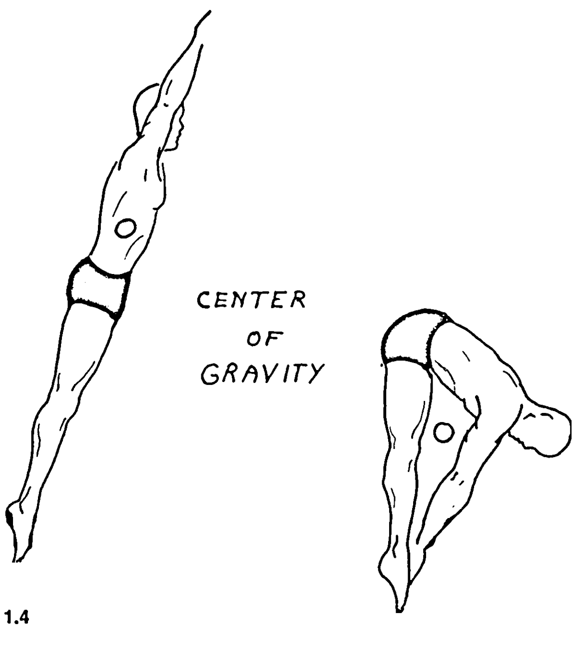


1.4

1.2
Moving the arm across the chest to the left will twist the body to the right.

1.3
When a pike position is opened in the air, the legs move away from the arms, and the arms move away from the legs.

1.4
The center of gravity doesn't always fall within the body.

Conservation of Angular Momentum

Aside from the introduction of outside forces, the angular momentum of a body is conserved. It is constant. This means that once he is spinning and has left the board, a diver will continue to have the *same* angular momentum until he hits the water. (Air resistance is negligible.)

When a diver tucks (thereby shortening the radius of gyration), then according to the law of conservation of angular momentum the spin must speed up. Remember: the moment of inertia times the angular velocity (the speed of the spin) equals the angular momentum. If one value is decreased, then the other must increase to conserve the angular momentum (the spin speeds up). When the diver moves his weight away from the spinning axis, the moment of inertia increases, and the spin slows down to conserve the angular momentum.

Inertia

Inertia refers to the tendency of a body's momentum to remain constant, when at rest to remain at rest, or when in motion in a straight line to remain in motion unless acted on by outside forces. For example, if a car is suddenly braked to a stop, the people sitting in the car lurch forward. Since they had momentum forward when the car stopped, they continue forward because of inertia. The friction of their bodies against the seat stops them—sometimes. A diver moves forward during his hurdle. When he lands on the end of the board, the body continues to move forward as the feet are stopped by friction. A forward lean results even if the diver lands on the end of the board vertically. (See Chapter 2.)

Friction

Friction is the resistance objects have to being pushed or dragged across one another. When two flat surfaces are put together, friction makes it difficult to pull one along the other. Friction is what enables a diver to walk on the board and to land on the end without sliding off. The rougher the surface, the greater the friction. (This is why board surfaces are embedded with nonskid material.)

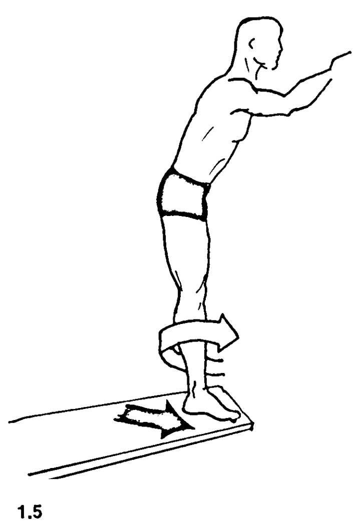
Centrifugal Force

Centrifugal force pulls a moving body outward when it is moving in a circular path. The classic representation of this is a bucket of water swung in a circle; the water doesn't pour out of the bucket when it is upside down because of the centrifugal force of the water against the bottom of the bucket.

Torque

Torque is a force or combination of forces that tends to produce a rotating or twisting motion about an axis. In diving, a torque must be introduced for twist or spin to occur. In a half twist layout, the torque is usually introduced by pushing the feet sideways as well as forward against the board as it lifts. (1.5)

1.5
Introducing the torque for a half twist from the board.



1.5

The Body Axes

An axis is an imaginary axle around which a body rotates. When a diver spins or twists, he always turns around an axis. The center of gravity of the body *always* falls within the spinning axis.

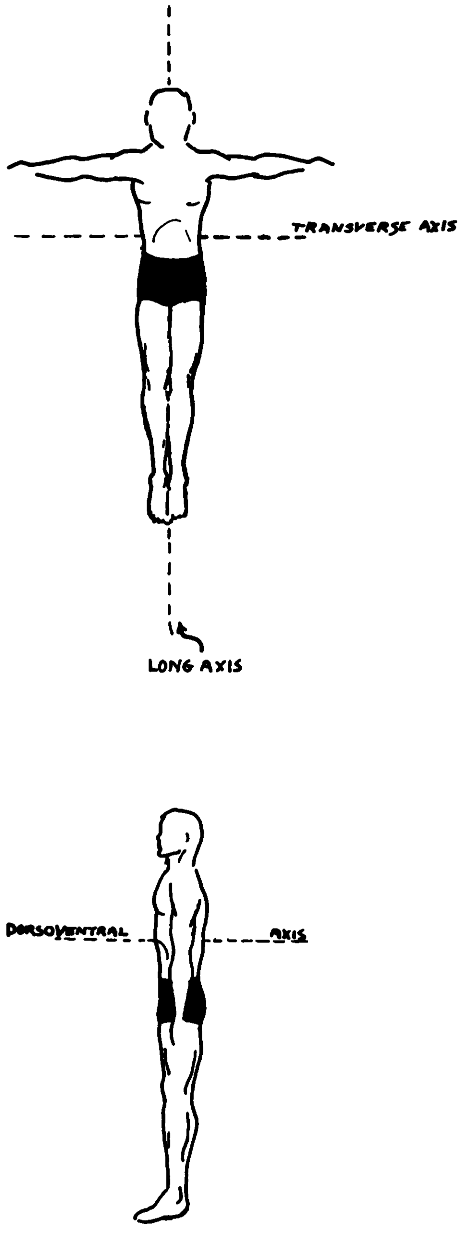
There are an infinite number of axes around which a body may rotate, but for the purposes of diving there are three. (1.6)

The Transverse or Lateral Spinning Axis: This side-to-side axis is the one around which the body rotates when doing a forward, backward, inward, or reverse spinning dive.

The Dorsoventral Axis: This is the front-to-back axis, an imaginary pole entering the chest and going out the back. The body turns somewhat on this axis when a twister is started from a pike or layout spinning dive. The body in these dives turns sideways, as in a cart-wheel, around the dorsoventral axis.

The Vertical or Long Body Axis: This is the up-and-down axis, the one from the head to the feet. Whenever the body twists in a dive, the body is turning on the long or vertical axis.

In a full twisting one-and-a-half somersault, for example, the body will be turning around all three at some time in the dive: the lateral when it spins forward, the dorsoventral when the arms are circled and the body tipped off the forward spinning axis, and around the vertical body axis during the twist.

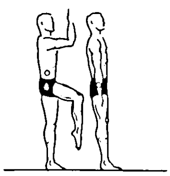


1.6
The body axes.

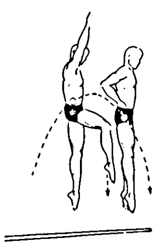
The Path of a Projected Body

When a body is projected at an angle upward (as in a hurdle or a dive), the center of gravity of the body moves in a parabolic path with the horizontal velocity remaining constant.

This path of the center of gravity will be unalterable, regardless of the changes in the shape of the body itself, without the introduction of an outside force. For example, when a diver leaves the board for any dive, whether he spins into a two-and-a-half somersault, twists, goes forward or reverse, the path of the center of gravity remains unalterably the parabolic one described. However, the body position and the distribution of its mass around the center of gravity may change. When this occurs while a person is standing on the ground, as when he moves his arms and/or leg up and down, the center of gravity moves up and down within the body.



When this happens in the air, the distribution of the body mass around the center of gravity changes because the center of gravity *must* stay in the projected path. For example, in the air during a hurdle when the lifted knee moves down, the body moves up because the center of gravity must stay in its parabolic path (and the position of the center of gravity is changed within the body).



For good boardwork this is an important principle to understand, as it determines the type of hurdle that is desirable for a particular dive. (See Chapter 2.)

[1]The terms mass and weight can be interchanged as far as diving is concerned because the pull of gravity is constant.