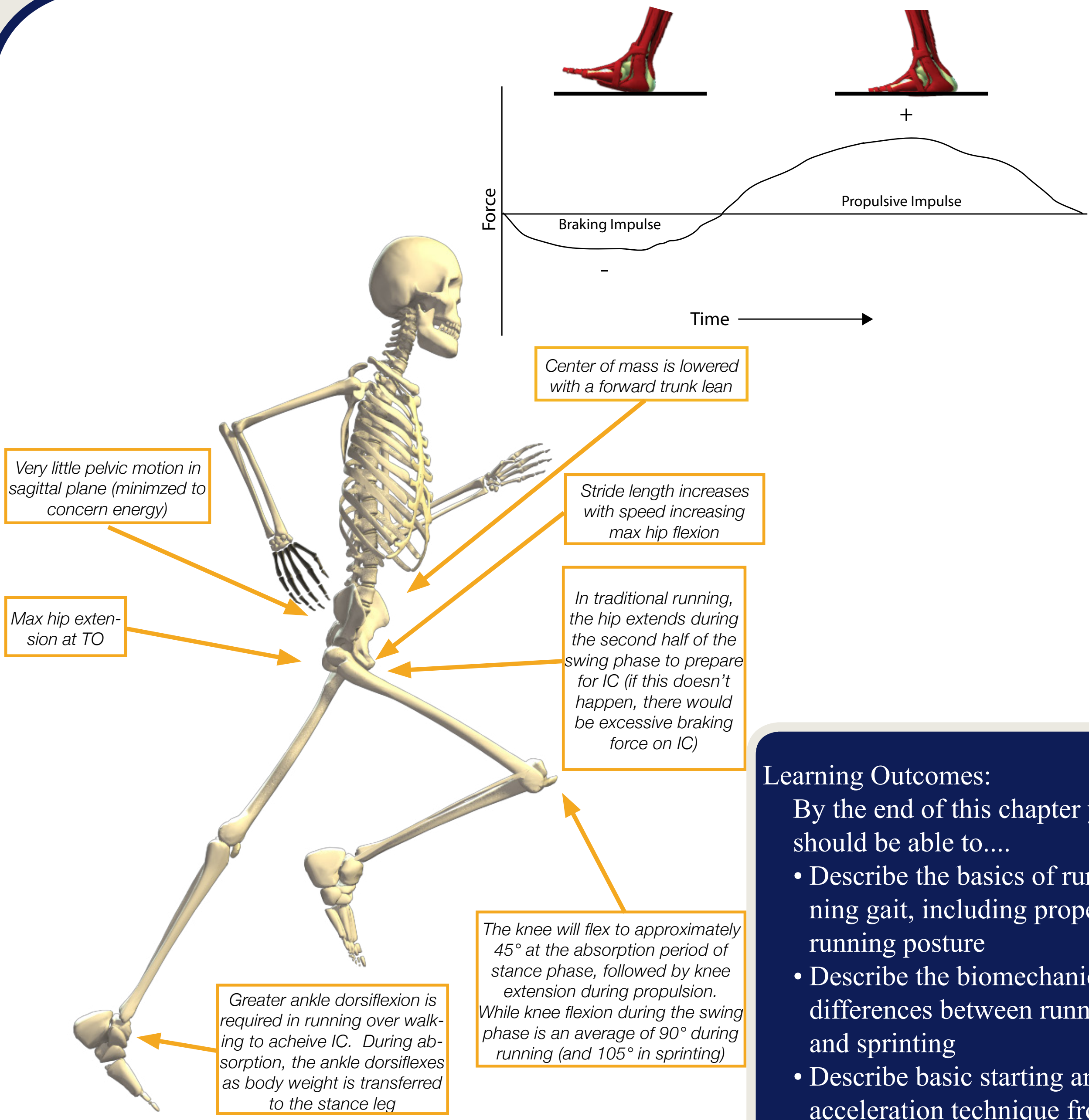


Learning Outcomes:

By the end of this chapter you should be able to....

- Describe the basics of running gait, including proper running posture
- Describe the biomechanical differences between running and sprinting
- Describe basic starting and acceleration technique from a static position
- Describe basic technique for reaching top speed
- Assess basic running gait and determine proper course of action for correction when needed

CHAPTER SEVEN
RUNNING SPEED

Science of Running Speed

1.1. Issac Newton and Running....

Sir Issac Newton, a 17th-18th century English physicist and mathematician created three laws that describe the statics (study of forces that do not cause changes in motion) and dynamics (study of forces that do cause changes in motion) of objects. Statics studies the forces on an object at rest and dynamics studies how forces affect the motion of an object.

***Newton's First Law of Motion: (Law of Inertia*) An object continues in its state of rest or of uniform speed in a straight line unless it is compelled to change that state by forces acting on it.**

What this means is that…

...An object at rest stays at rest or maintains its trajectory unless another force acts upon it causing it to change. Inertia is simply an object's ability to resist movement/motion. It requires more energy to get an object moving or to change it's direction than to keep it moving in a constant direction.

A good example of this is throwing a ball. Once the ball is thrown, it will keep on going at the same velocity (speed and direction) unless another force changes the ball's trajectory (path). On earth there is air friction that pushes against the ball. Gravity also changes its direction by making it fall down toward the earth. Finally, the ball stops when it hits the ground. Therefore, air friction, gravity, and the resistance of the ground are forces acting on the ball.

***Newton's Second Law of Motion: (Law of Acceleration*) The acceleration of an object is directly proportional to the net force acting on it and is inversely proportional to its mass. The direction of the acceleration is in the direction of the applied net force.**

What this means is…

...An object's acceleration is directly related to the force acting on it. The object will move in the direction of that force acting upon it.

If you push a bike, it will accelerate in the direction you are pushing it. It will also accelerate faster if you push it harder (greater force).

This concept is important in technique analysis in order to appreciate the how, what, and why something is happening.

***Newton's Third Law of Motion: (Law of Action-Reaction*) Whenever one object exerts a force on a second object, the second exerts an equal and opposite force on the first object.**

What this means is that…

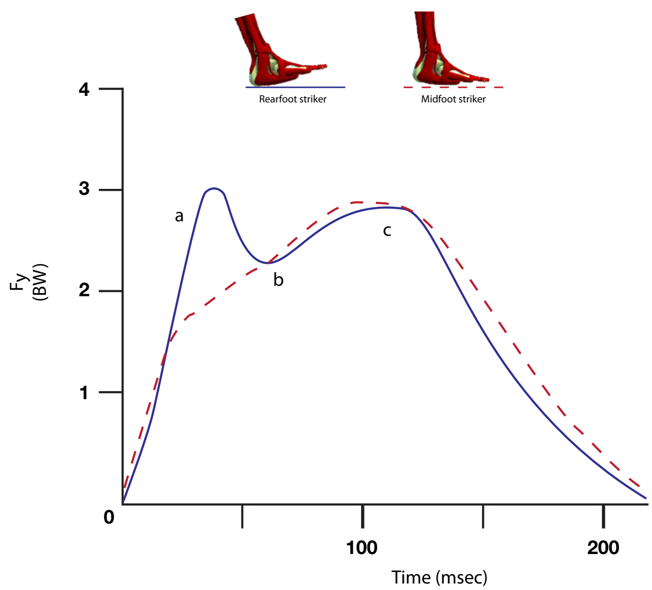
...During an action such as a foot-strike while running, there is a ground reaction force (GRF) (a fundamental force in the world of biomechanics). The force generated against the earth is the same as the force the earth is generating back. The difference is that the body's mass is insignificant in comparison to the earth's. Therefore the body will move upward against gravity rather than the earth moving away from the body.

1.2. Running and Ground Reaction Forces

Force vectors (when you think vectors, think arrows) can be broken down into x, y, and z components. Don't worry, no math is needed for this course! Let's take a look at two of the components that make up the GRF at foot-strike. These components are the vertical (F_y) and the horizontal component (F_x).

1.2.1. The Vertical Component - F_y

Ground reaction forces at each foot-strike are studied extensively for performance enhancement and in the investigation of running-related injuries. The vertical component of the GRFs during running is 2-3 x bodyweight depending on running style. Runners are typically classified as rearfoot, midfoot, or forefoot strikers (depending on the portion of the shoe that tends to contact the ground first).



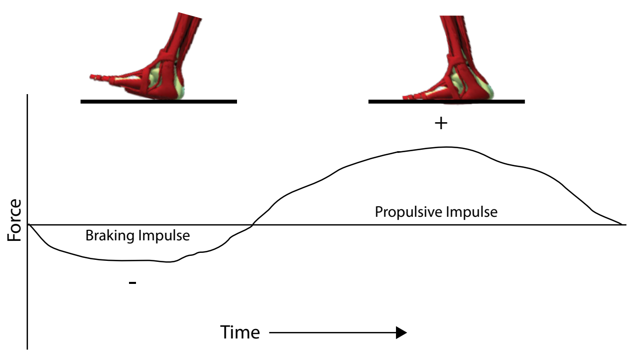
The above graph shows the vertical component of the GRFs for a rearfoot striker and a midfoot striker. There is a larger impact peak (point a) for the rearfoot striker, followed by a slight decrease (b) then a propulsive peak (c).

1.2.2. The Horizontal Component - F_x

Let's go back to the concepts of momentum and impulse. Momentum can simply be viewed as a measurement of motion of an object. Impulse can viewed as the amount of force (a push or a pull) on an object over a period of time that changes the object's momentum (movement).

Runners generally increase stride length as running speeds increase. Longer strides tend to generate GRFs with a larger "braking" horizontal component. This is one reason why overstriding can be counterproductive. Research has shown that a braking horizontal component force of 6% of bodyweight can increase the metabolic cost of running by up to 30%. This is wasted effort.

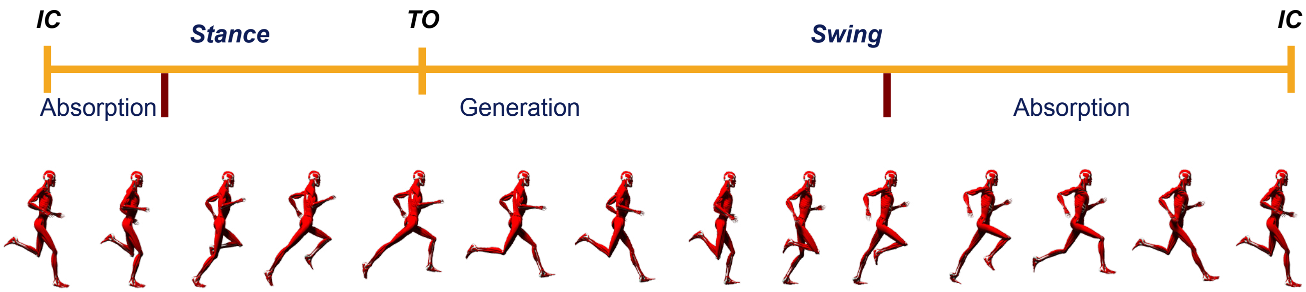
Look at the graph below. This graph represents the horizontal GRFs (F_x) over time of an overstrider. Notice that the initial horizontal force over time (or impulse) is pressing forward into the ground so the ground reaction force (F_x) is backwards. It's a braking force that slows performance! Only later in the stance phase (the phases of gait will be covered in a later chapter) do the forces switch directions. The body creates a backwards force and the GRF creates a propulsive force to accelerate us forward. To increase efficiency during running, braking forces must be reduced and propulsive forces increased.



1.3. The Gait Cycle

Running gait is different from that of walking and sprinting, but they are still broken down into the same two basic phases - the ***stance*** phase and the ***swing*** phase. In addition, each phase can be broken down into ***early***, ***mid*** and ***late*** stages.

Phase	Description	Early	Mid	Late
Stance	Foot is touching the ground. In walking there is a double-support stance phase (i.e. a time when both feet are touching the ground)	***Initial Contact (IC)*** - when foot initially touches the ground	Leg is under body and there is a mechanical reversal from ***absorption*** (deceleration) to ***generation*** (acceleration)	***Toe Off (TO)*** - when the foot starts to leave the ground. It is the transition from Stance to Swing
Swing	Foot is in the air and not touching the ground. In running there are two periods of float (***flight***) at the beginning and end of the swing phase (i.e. a time when neither foot is touching the ground)	***Toe Off (TO)***	Swing phase reversal, from generation to absorption	***Initial Contact (IC)***



Runners are typically characterized in one of three categories:

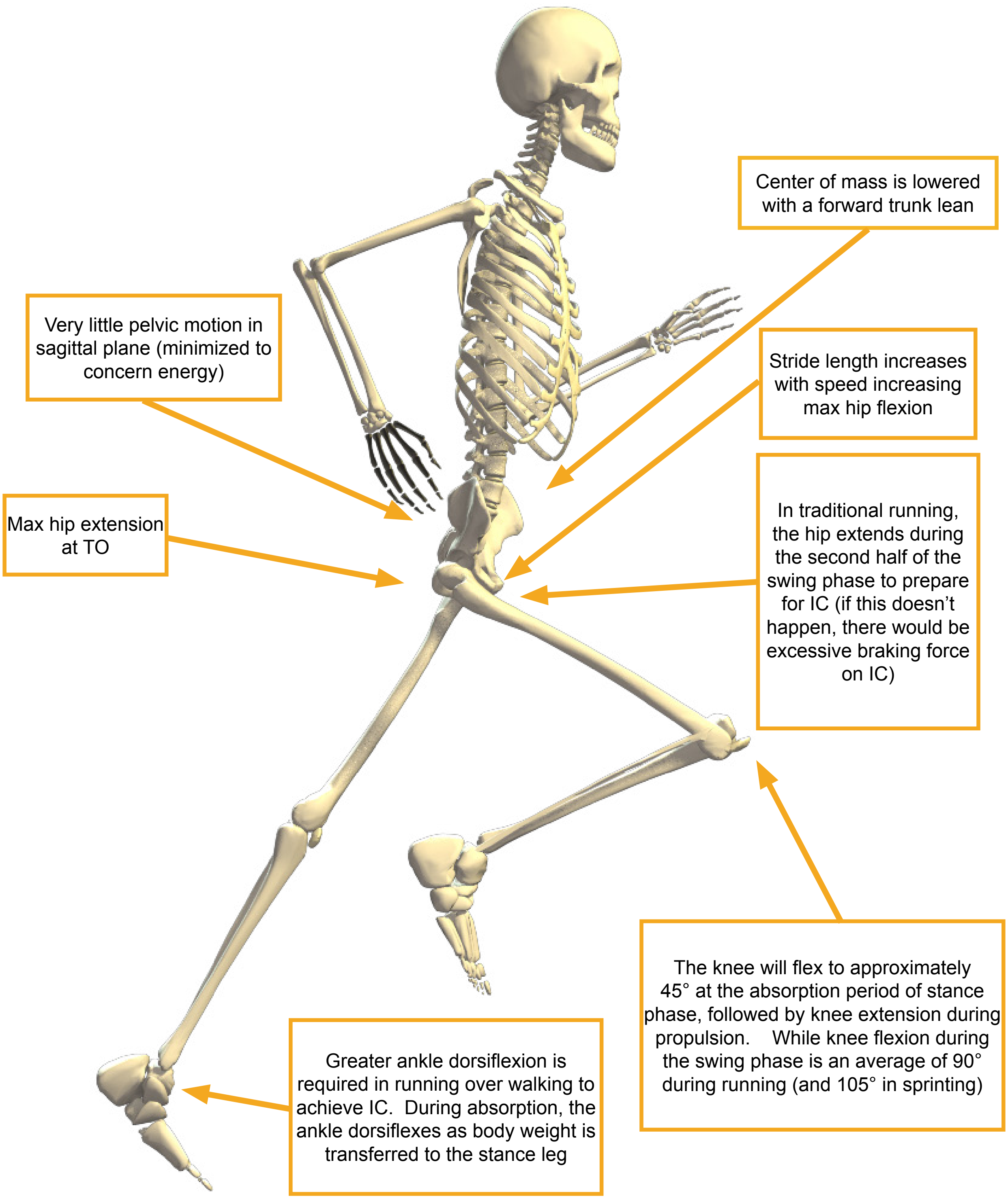
- Rearfoot Strikers (approx. 80% of distance runners are rearfoot strikers)
- Midfoot Strikers
- Forefoot Strikers

1.3.1.Running Kinematics - Standard Running Gait

As a quick review, kinematics is the study of motion without regard to the forces that cause movement. When studying running kinematics, we are primarily concerned with looking at joint motion in all three planes of motion. While an individual will obviously have different peak values of motion (and timing of motion) dependent on their level of conditioning and speed, we will primarily be concerned with general patterns of joint movement in all three planes in each phase of running.

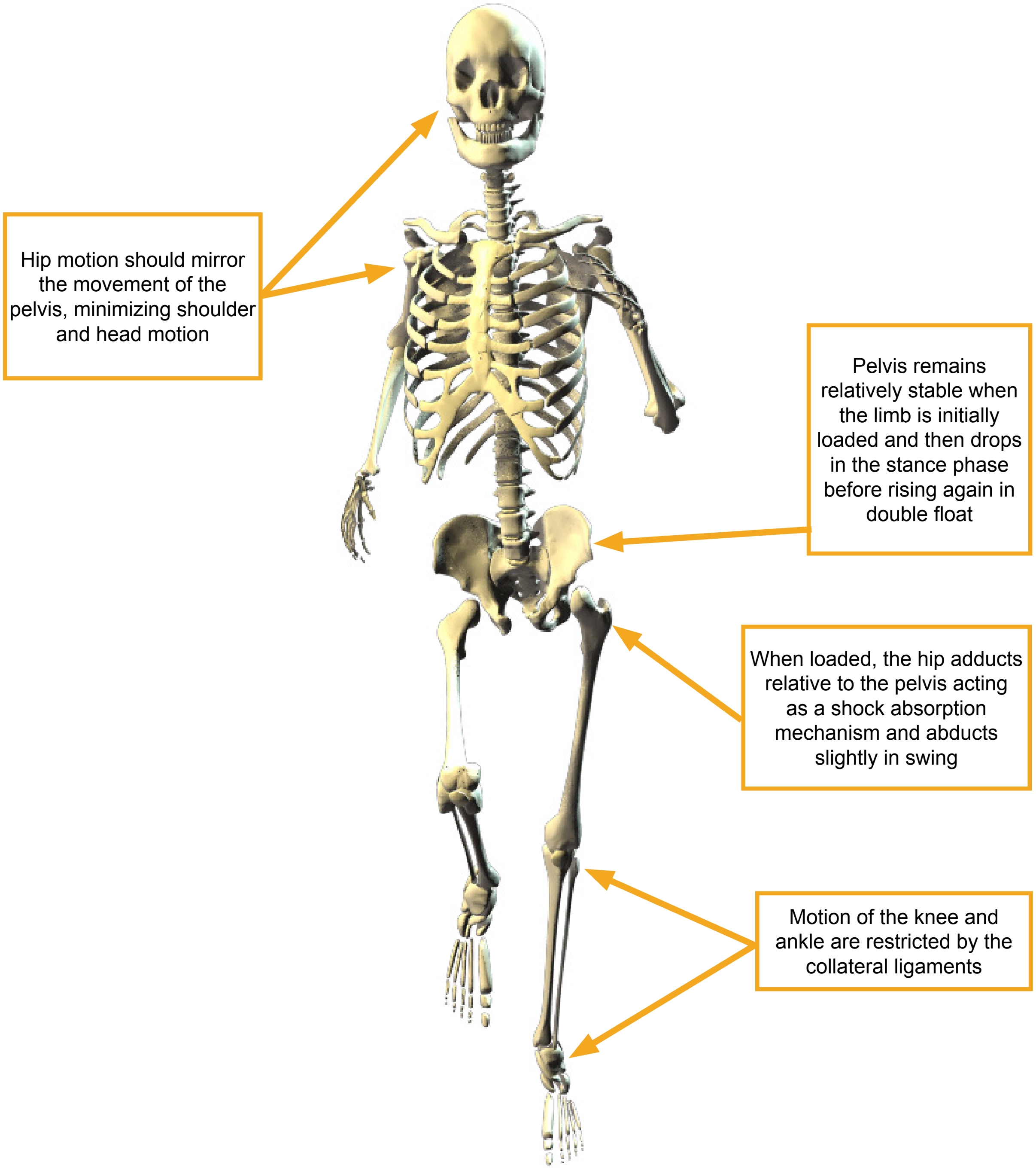
Sagittal Plane Kinematics

Traditional Running Technique



Frontal Plane Kinematics

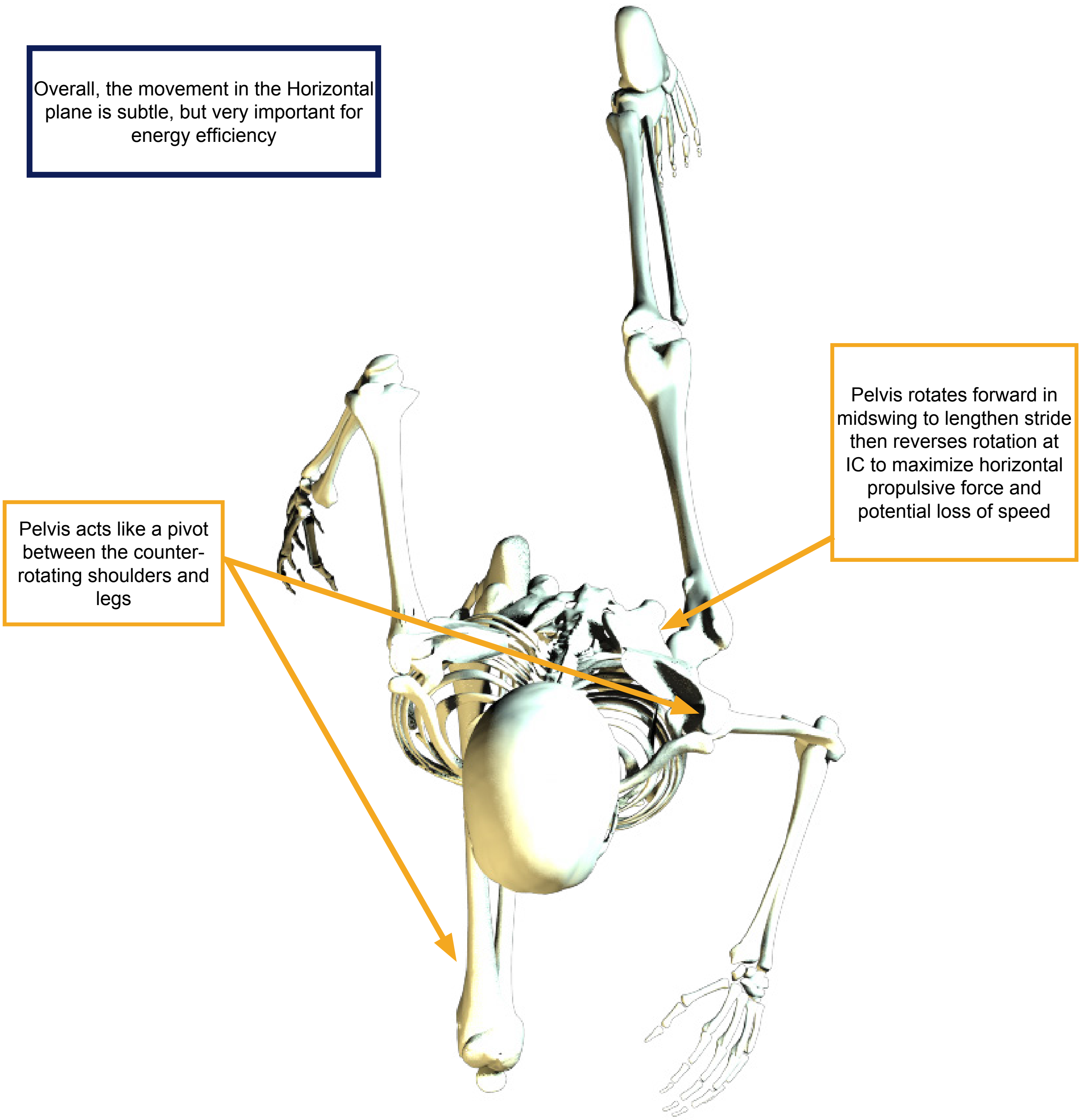
Traditional Running Technique



Horizontal Plane Kinematics

Traditional Running Technique

Overall, the movement in the Horizontal plane is subtle, but very important for energy efficiency



1.3.2. Pronation/Supination

Pronation/supination of the foot occurs about an oblique axis within the foot. Pronation occurs during the absorption phase while the limb is loaded. The foot then supinates during generation phase prior to push-off.

Obviously, ankle-foot biomechanics are very complex and the goal of this manual is only to cover the basics. What should be noted is that pronation and supination are natural motions needed in gait. Over-pronation (a.k.a. hyper-pronation, abnormal, excessive) is a case where altered foot mechanics can lead to injuries up the kinetic chain to the knees, pelvis, low back and potentially even further. This can give a "knock-kneed" appearance. Basically, when the subtalar joint over-pronates, the medial arch of the foot collapses, the tibia internally rotates and the pelvis tilts forward. This results in a ***valgus stress*** (where the distal end of a segment deviates laterally with respect to the proximal segment).

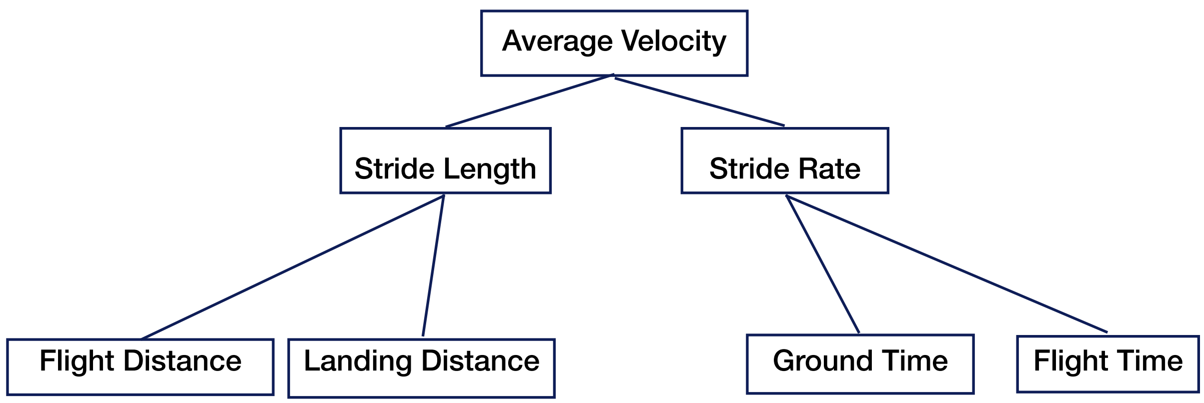
Underpronation (some call "supination") is less common and often referred to as "bow-legged". In this case, the altered mechanics results in a ***varus stress*** (where the distal end of a segment deviates medially with respect to the proximal segment). Please review the safety and injury prevention chapter for more information.

1.4. Running vs Sprinting

While the previous section described the basics of running gait, it is important to note that there are significant differences between running gait and sprinting gait.

Before addressing the details, it is important to note the ultimate goal is increased speed (obviously important in a Speed, Agility and Quickness program). Speed in running and sprinting is a function of stride length and stride frequency. While this may seem obvious, it's application is not easy because both variables are interdependent (i.e. as one variable increases the other often decreases). Hence, it is the job of the SAQ Specialist to assist their athletes in finding the optimal balance between stride length and stride rate..

Basic mechanics tells us that in order to accelerate an object a force must be placed upon it. Hence, it should not be a surprise to find out that research indicates that the force applied at ground contact is the most important determinant of running speed. However, the most elite sprinters have much greater flight time (when both feet are off the ground) than their less efficient counterparts. This means less relative stance/ground time (when the force propelling them is being applied). Hence better sprinters tend to produce greater force in a smaller period of time (i.e. increased rate of force development - RFD).



Bushnell and Hunter found that sprinters had greater hip flexion in the swing phase, greater knee extension at toe off, smaller contact (ground) time, longer stride length and knees were relatively closer at initial contact. While there were several other differences observed as well, the authors notated that the most important variable seems to be increased hip flexion. Increased hip flexion exhibits a quicker recovery of the leg and a reduction of breaking forces at initial contact (as the athlete is in a better position to initiate a backward force to accelerate forward).

The increased hip flexion is optimized by knee flexion, hence minimizing the leg's moment of inertia about the hip joint (this makes the movement quicker). Furthermore, the arms should swing in opposition. This counters the angular momentum generated by the swing leg. Like the knee, the elbow should have some flexion to reduce the moment of interia about the shoulder.

Lastly, full extension of the support leg and rotating the pelvis toward the side of takeoff can add several centimeters to stride length and hence more propulsive forces.

Young notated three primary goals of effective maximal sprinting:

1. ***Preservation of stability***
   - As with all athletic endeavours - one wants maximal efficiency and no waisted movement.
   - Specifically, the sprinter's trunk needs to be fairly rigid. This will keep the propulsive forces from being dissipated and absorbed by the trunk.
2. ***Minimization of breaking forces***
   - The sprinter's foot at initial contact should be directly below the sprinter's center of gravity.
3. ***Maximization of vertical propulsive forces***
   - While maximal horizontal velocity is the ultimate goal, also focusing on vertical propulsion allows one to optimize the sinusoidal motion of the sprinter's center of gravity.

Each of the above goals should be addressed by the SAQ Specialist in both the correction of the running gait as well as the individual drills utilized to reinforce instruction.

Please note, that the above theoretical model of sprinting is when the athlete would be in mid-sprint (after the athlete already had begun). In other words, if training for an event like the 100 m dash, each component of the event would have to be taken into account and trained. These would be:

1. The Start
2. The Acceleration Phase
3. The Velocity Maintenance Phase (which is what was described above)

Depending on the event or sport, one's training modality will be different. This should be obvious, as one would not train a 100 m sprinter exactly the same as a wide receiver for increasing sprint speed. However, there is much overlap in the drills one can utilize to train these athletes.