THE BIOMECHANICS OF SKIING

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This chapter provides background information on the biomechanics most relevant to skiing. It outlines how the muscles and skeleton function as a system to create balanced movement.

Bio Mechanics is the science of human bodies in motion. It combines the fields of mechanics (the physics of forces on objects in motion) and anatomy (muscles, bones and joints).

Skiing efficiently requires balanced movement which is a blend of skeletal strength and muscular strength.

Skeletal strength is when skiers are in an athletic stance and their body is balanced. The muscles have a functional amount of tension and the skier is supported primarily by skeletal strength. Bones stack on top of bones and there is minimal muscular action required to remain upright. If the skier moves away from the athletic stance muscles in the legs, abdomen, torso and neck must tighten/engage to keep an upright position. The skier is no longer relying on skeletal strength. The most efficient athletic stance involves a blend of skeletal and muscular strength that promotes the ability to move in any direction.

PROPRIOCEPTION

This is kinesthetic awareness, involving the awareness of movement and the orientation in space of the body and its various parts, through internal sensors called proprioceptors. Located primarily in the joints, muscles, tendons, and the inner ear, proprioceptors are responsible for the kinesthetic awareness of what our bodies are doing. Developing a skier's kinesthetic awareness is key to developing their ability to move accurately.

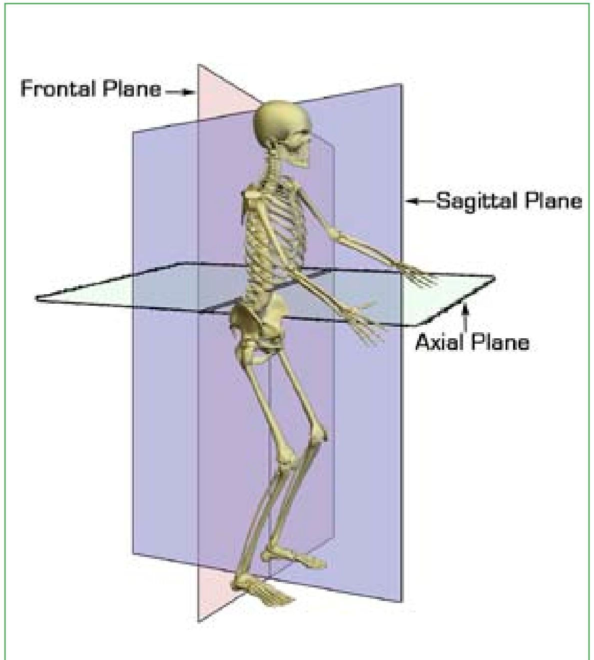
ANATOMICAL BODY PLANES

These describe movements of the body using planes or directions of movement.

For the purpose of most biomechanical descriptions, movement of the body is broken into three planes- sagittal, frontal and axial. The NZSIA uses four directions of movement to describe skiing. Fore/aft, rotational, lateral and vertical movement all exist within the three anatomical planes of motion as described below.

The anatomical body planes dissect the body vertically and horizontally which intersect at the centre of gravity:

- **Sagittal Plane –** a vertical plane that runs through the body from front to back or back to front. This plane divides the body into right and left regions. NZSIA fore/aft and vertical movements occur within this plane



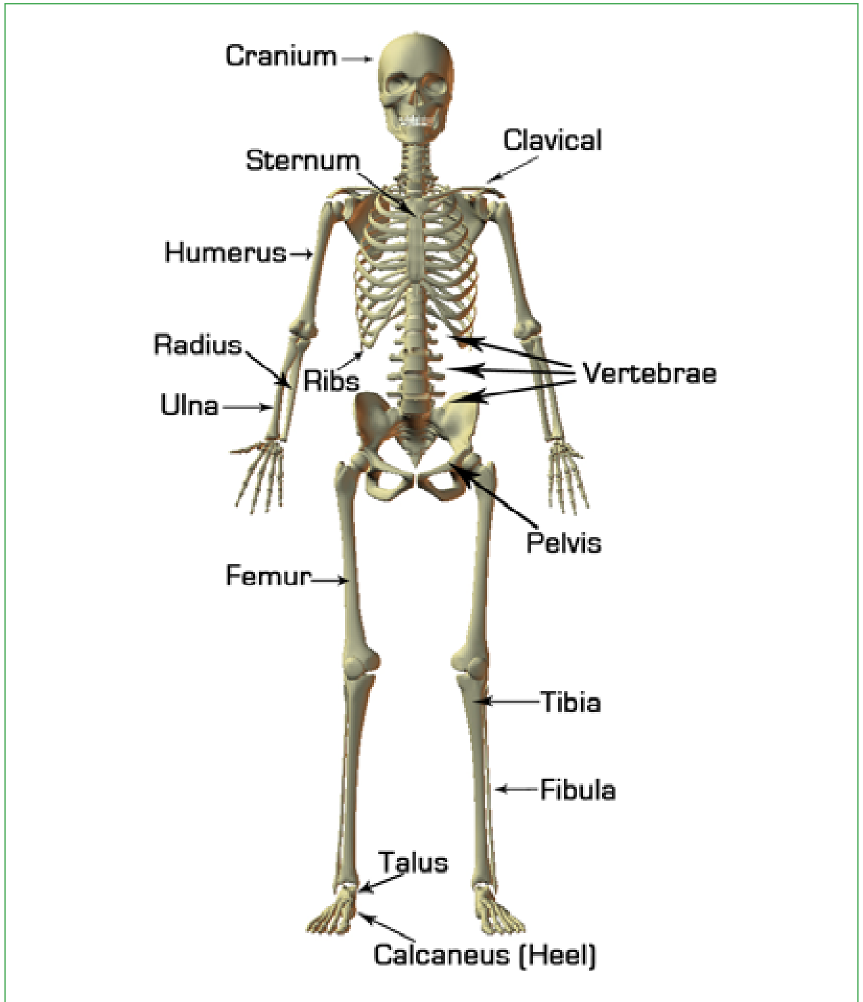
The Anatomical Planes of Movement

- **Frontal Plane –** a vertical plane that runs through the centre of the body from side to side. This plane divides the body into front and back regions. NZSIA lateral movement occurs within this plane

- **Axial or Rotational Plane –** a horizontal plane that runs through the midsection of the body. This plane divides the body or parts of the body into upper and lower regions. NZSIA Rotational movement occurs within this plane

4.1 THE HUMAN BODY

The body can be broken down into its component parts:
Bones are the underlying rigid structures that form the skeleton. Bones are connected by joints to which muscles are attached.



The Human Skeleton

4.2 ANATOMY OF THE SPINE

The spine is one of the more complex parts of the skeleton. The spinal column provides the main support for the body, giving it strength and enabling a person to stand upright. It is also flexible allowing the body to bend and twist in several planes while protecting the spinal cord from injury.

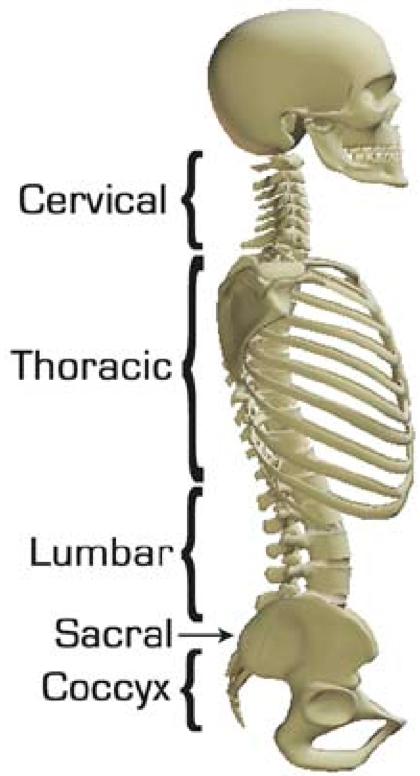
The spinal or vertebral column extends from the skull to the pelvis and is made up of 33 individual bones termed vertebrae.

The vertebrae are numbered and divided into regions: seven cervical, twelve thoracic, five lumbar, five sacral and four coccygeal. Only the top 24 vertebrae are moveable; those of the sacrum and coccyx are fused. The vertebrae in each region have unique features that help them perform their main functions.

- **Cervical region –** the main function of the cervical spine is to support the weight of the head. The cervical region has the greatest range of motion
- **Thoracic region –** the main function of the thoracic spine is to protect the organs of the chest by providing attachment for the rib cage. The range of motion in the thoracic spine is limited
- **Lumbar region –** the main function of the lumbar spine is to bear the weight of the body. These vertebrae are much larger in size for their weight-bearing function. The lumbar region has the second largest range of motion
- **Sacral region –** the main function of the sacrum is to provide attachment for the iliac (hip) bones and protect the pelvic organs. The five sacral vertebrae are fused together. Together with the iliac bones, they form a ring called the pelvic girdle
- **Coccyx region –** the four fused bones of the coccyx or tailbone don't really have a function

4.2.1 SPINAL CURVES

The spine has natural curves that form an S-shape. In an upright posture the spine is constantly being pulled forward by the weight of the body. Viewed from the side, the cervical and lumbar regions have a slight concave curve, and the thoracic and sacral regions have a gentle convex curve. The spine's curves work like a coiled spring to absorb shock, maintain balance and allow the full range of motion throughout the spinal column. These natural curves are maintained by the muscles in the front and back of the torso (the core) working in unison.



Regions of the spine

4.3 JOINTS

Joints are the place where two bones meet. All human bones, except for the hyoid bone in the neck, form a joint with another bone. Joints hold the bones together and allow the rigid skeleton to move.

4.3.1 TYPES OF JOINTS MOST RELEVANT TO SKIING:

- **Ball-and-socket joint –** the most mobile of all joints. Consists of a bone with a slightly egg-shaped head that articulates with the cup-shaped cavity of another bone. Ball and socket joints have a wider range of motion than other joints, permitting movements in all planes, as well as rotational movement around a central axis. The hip and shoulder are ball and socket joints
- **Gliding joints –** the articulating surfaces are nearly flat or slightly curved. These joints allow sliding or back-and-forth motion and twisting movements. Most of the joints within the wrist and ankle, as well as those between adjacent vertebrae, are gliding joints
- **Hinge joint –** the convex surface of one bone fits into the concave surface of another. Such a joint resembles the hinge of a door in that it permits movement in one plane only. The elbow is a hinge joint while the knee is a modified hinge joint

4.3.2 TYPES OF JOINT MOVEMENTS:

- **Flexion –** bending parts at a joint so that the angle between them decreases and the parts come closer together (bending the leg at the knee). Increasing angle with the frontal plane
- **Extension –** straightening parts at a joint so that the angle between them increases and the parts move farther apart (straightening the leg at the knee). Decreasing angle with the frontal plane
- **Abduction –** moving a part away from the midline (lifting the leg away from the body to form an angle with the side of the body). Moving away from the sagittal plane

- **Adduction –** moving a part toward the midline (returning the leg from being away from the body to align with the body). Moving toward the sagittal plane
- **Rotation –** moving a part around an axis of a bone (twisting the head from side to side, turning the whole leg from the hip joint). Medial or internal rotation involves movement toward the midline, whereas lateral or external rotation involves movement in the opposite direction (away from the midline)
- **Circumduction –** moving a limb in a circular manner, this requires a combination of flexion, extension, abduction and adduction. The ball and socket joints of the hip and the shoulder are two of only a few joints that are capable of circumduction

4.3.3 THE ANKLE JOINT

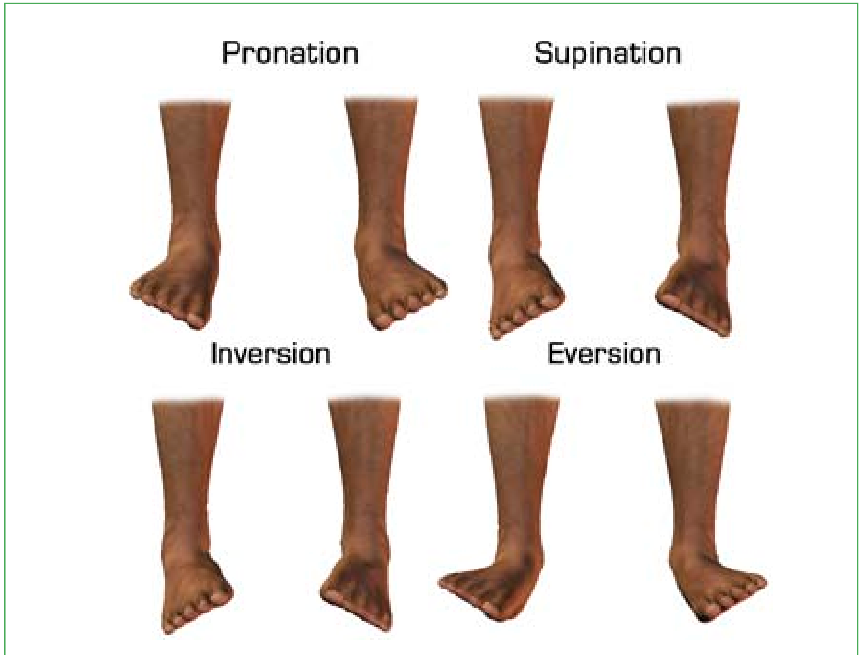
This is an important joint in skiing because it joins the two bones of the lower leg (Tibia and Fibula) to the talus bone of the foot. It is a hinge joint which can move the foot down (plantarflexion), and up (dorsiflexion). When the lower leg is moved onto the boot tongue while skiing the ankle movement is dorsiflexion.

Dorsiflexion and Plantarflexion

4.3.4 THE FOOT

The rest of the movements of the ankle and foot – twisting, tipping and side to side motion – occur in the complex system of bones in the foot and in the subtalar joint in combination with the muscles, tendons and ligaments in the ankle. This allows the movements of:

- **Pronation –** turning the foot so the sole faces outward or laterally (big toe side rotates down)
- **Supination –** turning the foot so the sole faces inward or medially (little toe side rotates down)
- **Eversion –** involves turning the sole of the foot outward. It combines lateral rotation (toeing out) with pronation (rotating the little toes side of the foot upward)
- **Inversion –** involves turning the sole inward combines medial rotation (toeing in) and supination (rotating the big toe side of the foot upward)

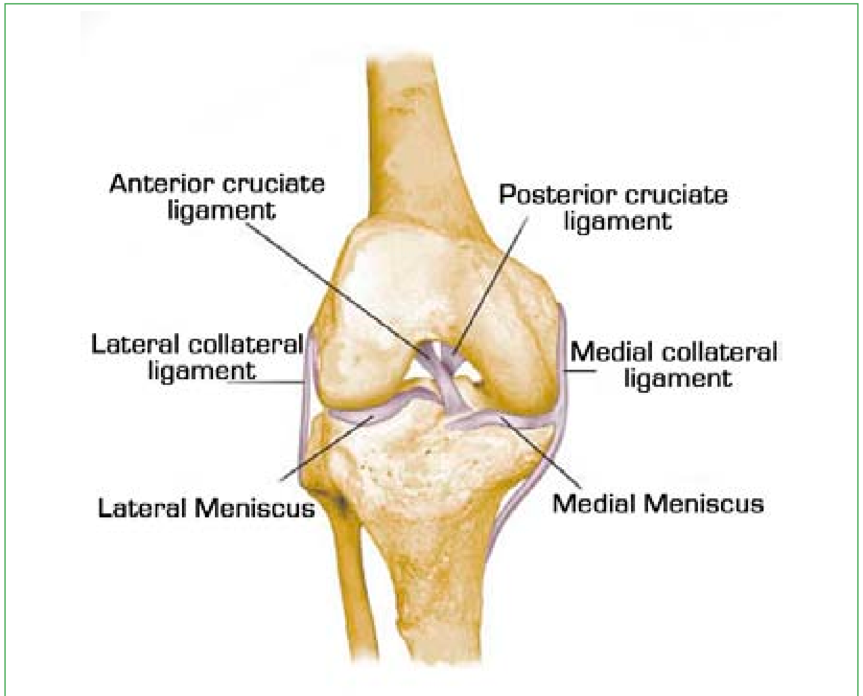


Pronation and Supination / Inversion and Eversion

Ankle movements are critical to good skiing but they are restricted by the ski boot. Fine edge control movements begin in the ankles and ankle tension is essential to make the skis hold. Active engagement of the ankle muscles is important for changing edges during turn initiation.

4.3.5 THE KNEE JOINT

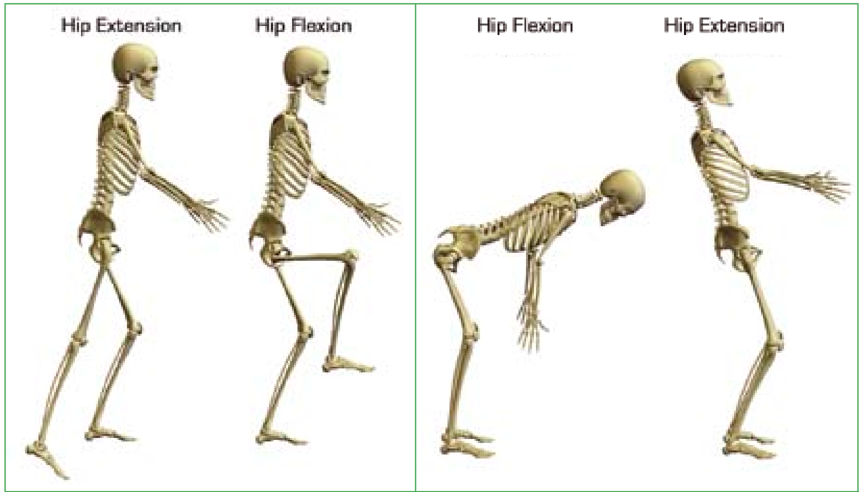
As a hinge the knee joint has normal ranges of movement of flexion and extension, although a small amount of rotation and lateral movement is also possible.



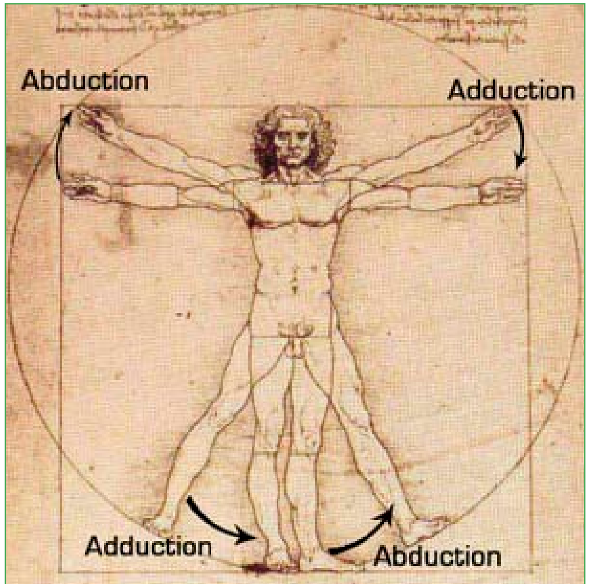
Structure of the Right Knee Joint

4.3.6 HIP JOINT

The hip joint has normal ranges of movement of flexion, extension, abduction, adduction, medial rotation and lateral rotation.



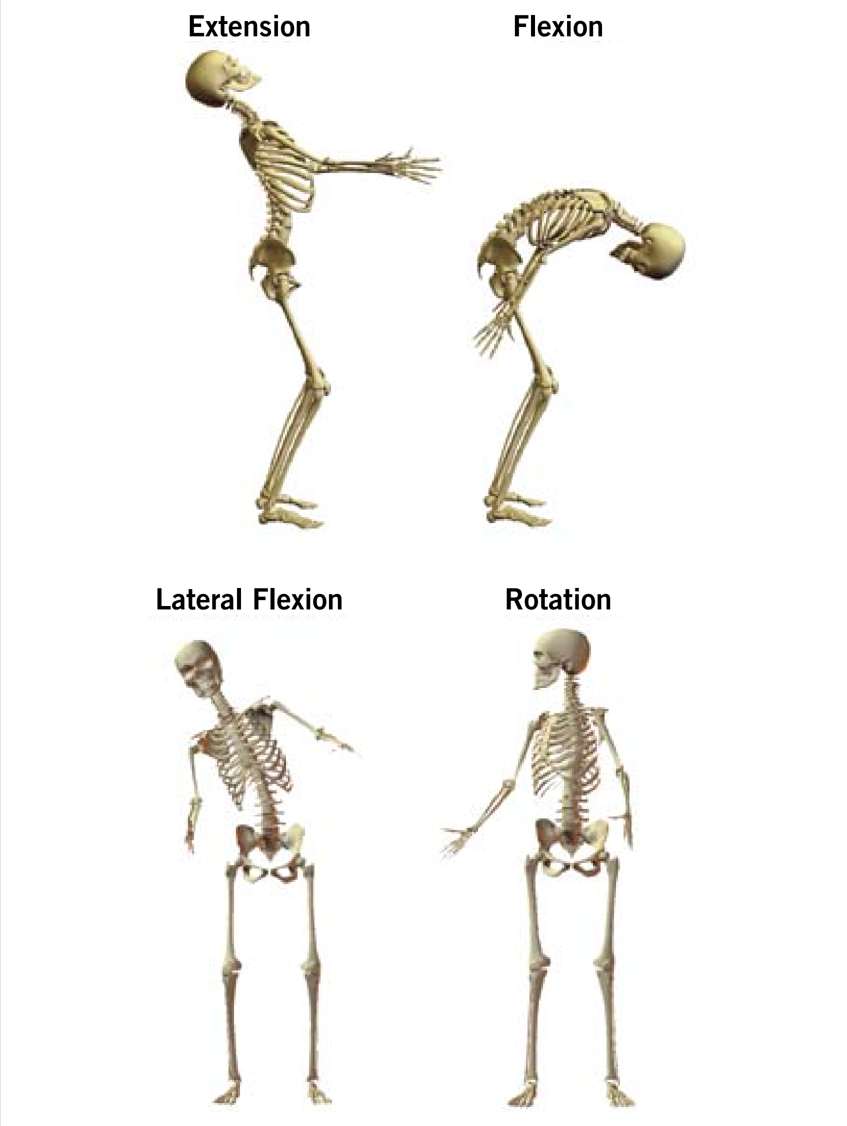
Hip flexion and hip extension



Adduction and abduction

4.3.7 SPINAL COLUMN

The vertebral column has normal ranges of movement of flexion, extension, lateral flexion and rotation.



Movements of the spine

4.4 MUSCLES

The function of muscles is to produce force and cause motion. Muscles function in pairs to produce movement and when the first muscle contracts, the second muscle relaxes to allow movement. When the second muscle contracts the first muscle relaxes to allow movement in the opposite direction. The relationship between these muscle pairs is referred to as "antagonists."

Flexion and extension, abduction and adduction, rotation, supination and pronation and eversion and inversion are opposite movements that are controlled by muscle pairs.

CONCENTRIC CONTRACTION

A concentric contraction is a type of muscle contraction in which the muscles shorten while generating force. Concentric contraction causes the muscle to shorten and change the angle of the joint.

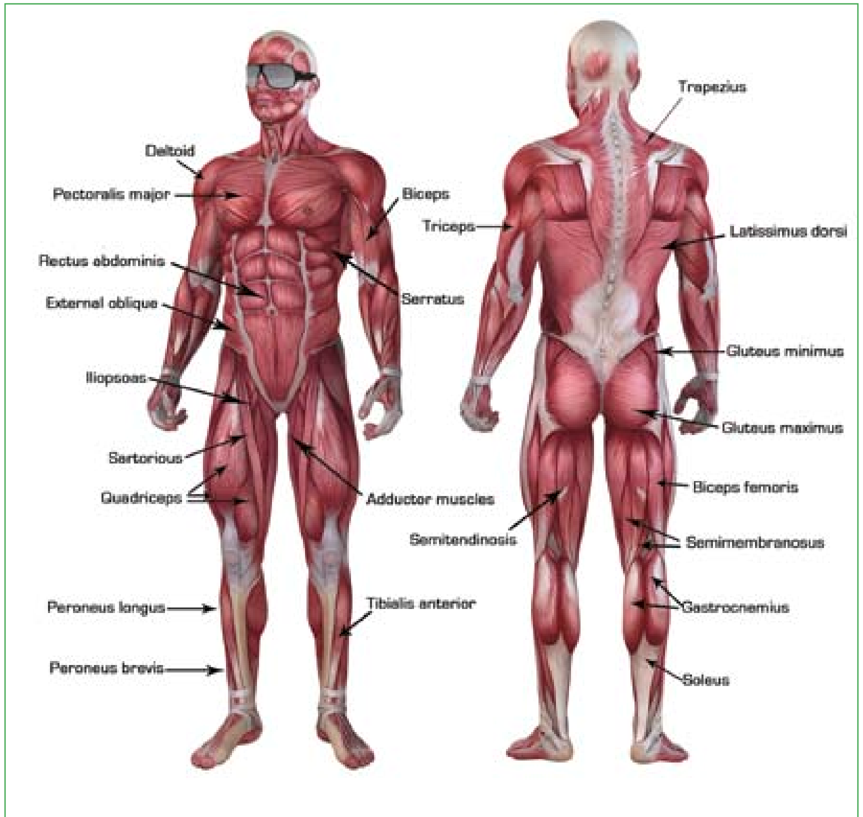
ECCENTRIC CONTRACTION

During an eccentric contraction the muscle elongates while under tension due to an opposing force being greater than the force generated by the muscle. Rather than working to pull a joint in the direction of the muscle contraction, the muscle acts to decelerate the joint at the end of a movement, or otherwise control the repositioning of a load. This can occur involuntarily (when attempting to move a weight too heavy for the muscle to lift) or voluntarily (when the muscle is smoothing out a movement).

Eccentric contractions normally occur as a braking force in opposition to a concentric contraction to protect joints from damage. During virtually any routine movement, eccentric contractions assist in keeping motions smooth, but can also slow rapid movements, e.g. in skiing, smoothing out the vertical movements - flexion and extension.

ISOMETRIC CONTRACTION

An isometric contraction of a muscle generates force without changing length, e.g. the muscles of the hand and forearm grip the ski pole, and after the pole has been gripped the joints of the hand do not move, but muscles generate sufficient force to prevent the pole from being dropped.



Muscles of the human body

4.4.1 MUSCLES OF THE LOWER LEGS

- **Ankle Inverters –** the tibialis anterior and gastrocnemius muscles help to elevate the arch and therefore transfer more pressure to the outer border of the foot. Ankle inversion helps to maintain good medial and lateral alignment.
- **Ankle Everters –** the peroneus longus and brevis evert the ankle. These act to flatten the arch which places more pressure on the medial border of the foot. Ankle Everters help maintain good load distribution and medial and lateral alignment
- **Ankle Dorsiflexors –** the tibialis anterior is responsible for dorsiflexion. The function of dorsiflexion (lifting the top of the foot toward the shin) helps maintain fore/aft balance and helps to balance the leg and foot to stabilise the leg on uneven ground. These muscles are most active during short turns and bump skiing
- **Ankle Plantarflexors –** the gastrocnemius and soleus (calf) muscles act together to pull the foot down, away from the shin. These muscles are used to press the ball of the foot into the boot and are extended when the foot is in dorsiflexion
- **The Gastrocnemius and Soleus Muscles –** the action of the calf muscles also include flexing the leg at the knee joint and the development of tension. They are powerful muscles and vital in skiing. The soleus plays an important role in maintaining standing posture because if not for its constant pull, the body would fall forward

4.4.2 MUSCLES OF THE KNEES AND LEGS

- **Knee Extensors –** the quadriceps femoris is a large muscle group consisting of four muscles on the front of the thigh which act together to extend or straighten the leg
- **Knee Flexors –** the hamstring is a group of three muscles that act together to bend the knee. The hamstrings also provide stability at the knee joint helping the anterior cruciate ligament to prevent forward movement of the tibia on the femur. The hamstrings oppose the quadriceps to flex the leg

4.4.3 MUSCLES OF THE PELVIS AND LEGS

- **Hip Extensors –** these enable movement of the thigh behind the torso. In skiing these muscles, while in active contraction, will lessen flexion in the legs
  - gluteus maximus are the muscles surrounding the posterior of the pelvis. Strong "glutes" are important to resist the powerful forces of skiing
  - hamstrings are the large muscles of the back of the thigh opposite the quadriceps
- **Hip Flexors –** this group of muscles act to flex the femur towards the pelvis i.e. pull the knee upward. They are located at the front of the abdomen and leg and in skiing they are used in flexion movements.
- **Hip Rotators –** this group of muscles are found at the posterior of the pelvis and into the upper femur. The hip medial and lateral rotators are very important in balancing and supporting the other motions of the hip. They help stabilise the femur in the hip socket. These muscles rotate the femur at the hip joint. If the knees are pointed towards each other while standing the femurs are rotated medially (inwards). If the knees are turned away from each other the femurs are rotated laterally (outwards)
- **Hip Abductors –** these muscles enable the leg to move away from the midline of the body. The primary hip abductor is the gluteus medius. In combination with the hip adductors (inner thigh) these muscles are important in skiing for shifting weight to bring the centre of gravity into alignment with the supporting skeletal structure
- **Hip Adductors –** these are the inner thigh muscles and enable the legs to move toward the midline of the body. In skiing they are used to stabilise the skis. Rotation of the legs is a combination of rotation and abduction or abduction

4.4.4 MUSCLES OF THE TORSO AND CORE

- **The Spinal Extensors** are attached to the back of the spine and enable standing up and lifting objects. The extensors counterbalance the action of the abdominals
- **The Spinal Flexors** are in the front of the spine and include the abdominal muscles. These muscles when contracting concentrically enable flexion or forward bend. They are important in lifting and controlling the arch in the lower back

These muscles stabilise the spine and therefore the whole torso. In skiing they are responsible for enabling skiers to maintain fore/aft and lateral balance and providing a stable upper body to facilitate rotation of the legs.

4.4.5 ABDOMINAL MUSCLES - THE CORE

The abdominal muscles are a group of six muscles that extend from various places on the ribs to various places on the pelvis. These muscles provide postural support as well as enabling movement in the torso. They are often referred to as the core and also assist in the breathing process.

The more structurally deeper and closer to the spine the particular abdominal muscle is, the more effect it has over body posture. The six abdominal muscles all affect body posture.

From deep to superficial the abdominal muscles are:

- **Transverse Abdominal –** the deepest abdominal muscle and has the most effect on body posture. The transverse abdominal runs from the sides of the torso (lateral) to the front of the torso (anterior)
- **Internal Obliques (x2) and External Obliques (x2) –** these two pairs of abdominal muscles are on each side of the torso. The external obliques are more superficial. Both sets of obliques affect body posture, but slightly less because of their more superficial position. They are involved in rotation and lateral flexion movements of the spine

- **Rectus Abdominis –** is the most superficial of the abdominal muscles. It is a long flat muscle, which extends along the length of the front of the abdomen and together with the external obliques affects body posture, but not as much as the deeper abdominal muscles. This muscle is responsible for flexing the lumbar spine and as such maintaining accurate alignment of the pelvis

4.4.6 MUSCLES OF THE UPPER TORSO

- **Upper Back Muscles**
  - trapezius – a triangular shaped muscle that runs from the centre of the back up to the neck and across the shoulder blades. This helps to maintain good posture for the upper spine, neck and head
  - rhomboids – these muscles run from the base of the neck to the shoulder blade and help to hold the shoulders back and maintain good posture
- **Shoulder Muscles –** in skiing the shoulder muscles are important for good posture and stability of the torso and arms and consist of:
  - deltoid muscles which wrap right around the top of the shoulders giving the shoulders versatility and a greater range of movement
  - rotator cuff muscles, located beneath the shoulder, help to hold the arms in place
- **Chest Muscles**
  - pectorals – these run across the surface of the chest and in skiing help to stabilise the upper body including the arms
- **Arm Muscles**
  - biceps – located at the front of the upper arm and used to flex the arm at the elbow. In skiing used together with the forearm muscles and wrist in the pole swing
  - triceps **–** located at the back of the upper arms, these muscles oppose the biceps and come into play to extend the arm

4.5 CONNECTORS AND CUSHIONS

In addition to the muscles there are other soft tissues that help connect the body together:

- tendons are the tough fibrous cords that attach muscle to bone
- ligaments are the tough fibrous tissues that connect bones to other bones to form a joint
- cartilage forms the slippery surface of bone ends in joints

NOTES

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