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ACKNOWLEDGMENTS:

For their assistance and support I would like to thank Julie Reitman, Dan Connors, John Hight and Jack and Kathy Copeland. I would also like to extend a special thanks to Barbara Sanders and Tabby Mannetter for their assistance in the production of this manual.

Cover illustration by Sharon DeMattia

BIOMECHANICS FOR SKI INSTRUCTORS by Peter Isaacs

INTRODUCTION

Biomechanics: What is it?
Why do I need to know about this?
How can it make me a better instructor?

Biomechanics is the understanding of the body and its parts and how these parts are involved to produce motion. Specifically, for ski instructors, how the body parts interrelate to allow us to turn, edge and pressure our skis while staying balanced in varying conditions.

The more we know of these interrelationships the better able we are to determine what to focus on in a lesson; to best meet our students' needs and goals.
For example: A student with a straight downhill leg, upper body rotation and "Z" shaped turns; where do we start? Which of the four skills do we address first to allow development of the other three skills. Why is this situation very appropriate for a seven year old? By reading further and gaining a better knowledge of **Biomechanics** as it relates to skiing, these questions are easier to answer and our lessons become more successful.

It is my hope that this manual will enhance your knowledge and understanding of biomechanics as it relates to ski teaching and that you will be able to incorporate this knowledge to enhance the lessons you already teach.

BIOMECHANICS FOR SKI INSTRUCTORS

TERMS AND DEFINITIONS

1) **Muscles** - Connective tissue structures that have the ability to contract thereby creating movement and generating the force required to move bones and do work.

2) **Joints** - Where two bones come together, an articulation.

3) **Tendons** - The non-contracting part of a muscle that connects muscle to bone i.e. Achilles tendon.

4) **Ligaments** - Connective tissue that connects bone to bone i.e. Anterior cruciate ligament.

5) **Cartilage** - a) **Articular** - the "Teflon coating" found on the ends of bones to create low friction interfaces.
b) **Fibrocartilage** - the fibrous kind of cartilage found between that acts as a "spacer" and shock absorber; also known as meniscus.

6) **Synovium** - The membranous lining of a joint that secretes fluid - Synovial fluid is like the oil in an engine.

7) **Medial** - Toward the midline of the body.

8) **Lateral** - Toward the outside of the body.

9) **Anterior** - To the front of the body.

10) **Posterior** - To the back of the body.

11) **Flexion** - When two bones at a joint are brought together.

12) **Extension** - When two bones at a joint are moved apart.

13) **Abduction** - Away from the body, to the outside.

14) **Adduction** - Toward the midline of the body, to the inside.

15) **Internal Rotation** - To rotate an extremity or body part toward the midline.

16) **External Rotation** - To rotate an extremity or body part away from the midline.

17) **Flexors** - Muscles which serve to bend a joint (Agonist).

18) **Extensors** - Muscles which oppose Flexors (Antagonist). They extend a joint and can be a prime mover therefore is Agonist and Flexor is Antagonist.

△ 19) **Supination** - Weight bearing tends to be more on the lateral aspect of the foot.

■ 20) **Pronation** - Weight bearing tends to be on the medial aspect of the foot. Most commonly seen in women.

△ 21) **Inversion** - Weight bearing is on the lateral aspect of the foot with the foot turned medially.

■ 22) **Eversion** - Weight bearing is on the medial aspect of the foot with the foot turned laterally.

SOME BASIC CONCEPTS CONCERNING SKELETAL MUSCLES

1) Skeletal muscles function to produce movement, to maintain posture and body heat.

2) When muscles are not stressed and exercised, they tend to become smaller in the cross sectional area. Because of this atrophy they are weaker and not able to function as efficiently as if they were used more.

3) Unless muscles are stressed by continued usage during the school years, chances are they will never develop to their full capacity.

4) Muscles can contract in three ways:

a) They can shorten and pull towards the midline of the muscle called the belly. This is **concentric contraction**.

b) Muscles can also lengthen against resistance or in conjunction with the forceful flexion on the opposite side of the joint. This is called **eccentric contraction.**

For example - in sprinting, as the quads flex the thigh, the hamstrings on the other side of the joint must lengthen at the same speed. When the hamstrings can't maintain the same lengthening speeds, a muscle strain or pull is the probable result.

Since in both a and b above the length of the muscle changes, the general name used for this kind of muscular work is called **isotonic contraction**. Movement is created at the joint involved.

c) Muscles can also contract and expand energy without changing their length. This kind of action is used many times by the body to stabilize or fix certain joints so they can't move. This is called **isometric or static contraction**. There is no movement produced at the joint.

5) Muscles produce action in groups. Very seldom does a single muscle ever contract alone. A muscle can assume the following roles in producing movement:

a) A prime mover is a muscle whose action is primarily responsible for bringing about the action. An example would be the triceps and forearm extension.

b) An assistant mover is a muscle whose action aids the prime mover in the production of movement. An example would be the biceps brachii in supination of the forearm.

c) A stabilizer is a muscle which contracts to fix a joint so action in other joints can occur. The floor push-up is an example in which the abdominal muscles contract isometrically to fix the hips and maintain extension.

d) A neutralizer or synergist is a muscle that contracts in order to rule out or neutralize undesired muscular action at certain joints. This is a critical phase of coordinationin activities and is brought about by action of higher centers in the brain. Coordination can be improved by the selection of appropriate activities.

6) Each group of muscles has another group of muscles that is antagonist to its actions. Usually the two opposing groups are located on the opposite side of the joint. An example of this is the triceps and biceps. When the biceps contract and shorten, the triceps must relax and lengthen.

7) The following factors are closely associated with what can and does happen to a muscle during training:

a) Repeated use of muscles results in an increase in the size of the muscle, this is called hypertrophy. No new fibers are formed, the fibers increase their cross-sectional size. This produces sort of a "turgor" effect and is responsible for improved tone in muscle.

b) The total number of capillaries in a muscle also increases with training. This usually accompanies an increase in fiber size. Trained muscles may also be able to store more fuel and oxygen, thus increasing endurance.

c) Increasements in power and speed can be increased without an increase in the size of the muscle. In fact, studies have revealed that the power of a muscle can increase three-fold without a change in muscle volume.

Hence, lifting weights in a well planned program can have tremendous effects on strength and power without fear of developing "big, bulging muscles"

MECHANICS OF MOVEMENT

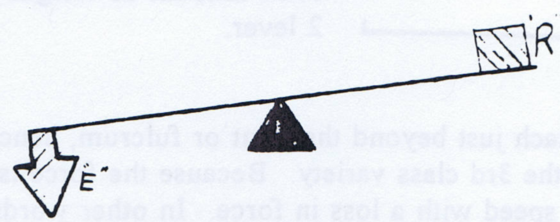
FULCRUM = JOINT

EFFORT = MUSCLE

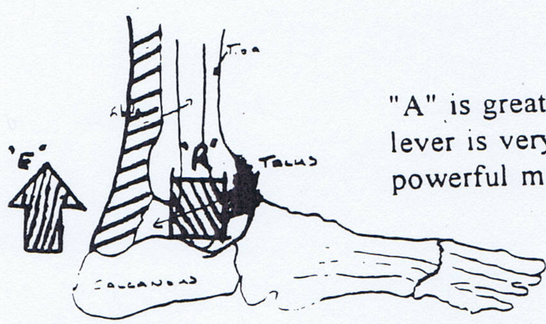
RESISTANCE = WEIGHT

In each case if the distance from the fulcrum to resistance "A" isgreater than the distance from the fulcrum to the resistance "B" then less effort is required.

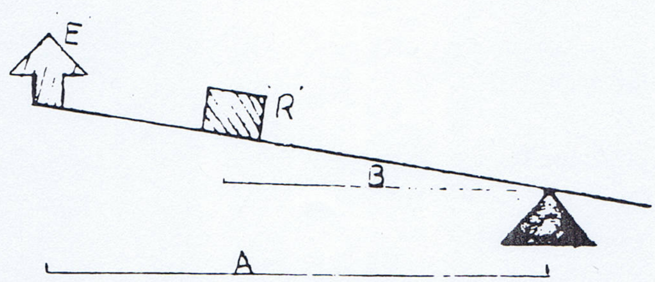
1ST CLASS LEVER: The fulcrum joint always lies between the resistance and the effort. This is the most efficient lever. With constant weight, the longer the distance the effort is from the fulcrum the less muscle effort is required.



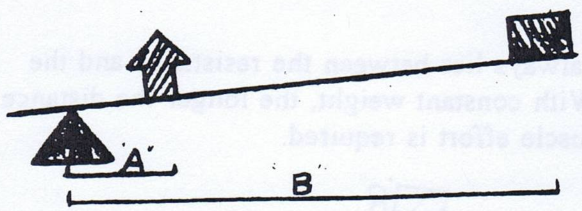
2ND CLASS LEVER: The resistance always lies between the fulcrum and the effort. Such as pushing/lifting a wheelbarrow. The longer the distance between the fulcrum and the effort relative to the shorter distance between the fulcrum and the resistance provides good mechanical advantage for the muscle lifting the body weight onto the heads of the metatarsals.



"A" is greater than "B therefore this class lever is very efficient. Little effort for powerful movement.



3RD CLASS LEVER: The muscular effort is placed between the weight and the joint, providing the least efficient mechanical advantage. To compare 3rd and 2nd class levers, lifting, a 50 lb. box with your arms takes significantly more muscular effort than lifting your 150 lb. body weight onto the balls of your feet.



"A" is much less than "B" - much more effort is required to move the same amount of weight as in a Class 2 lever.

Most muscles insert or attach just beyond the joint or fulcrum, hence, most of the levers of the body are of the 3rd class variety. Because the force is near the fulcrum the action results in great speed with a loss in force. In other words, muscular action must exert large amounts of force to move a comparatively small resistance, but the movement is done with great speed.

THE HIP JOINT

HIP JOINT

A true ball and socket joint often referred to as a universal joint. This is a very stable joint; aided by thick ligaments, especially the anterior ligaments, and some of the strongest muscles of the body.

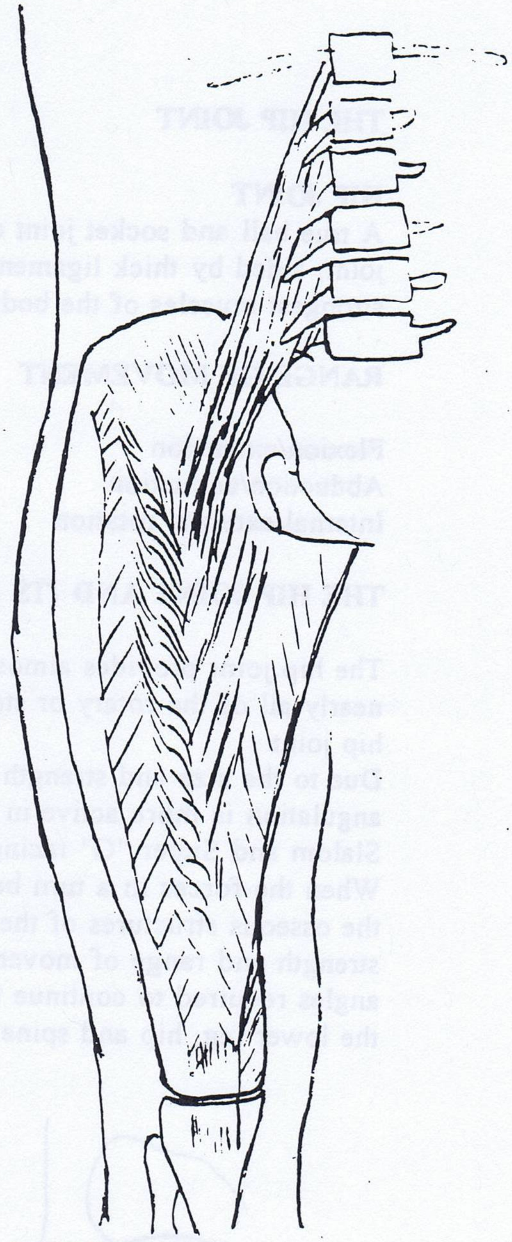
RANGE OF MOVEMENT

Flexion/extension
Abduction/adduction {Generally known as circumduction}
Internal/external rotation

THE HIP JOINT AND ITS IMPORTANCE TO SKIING

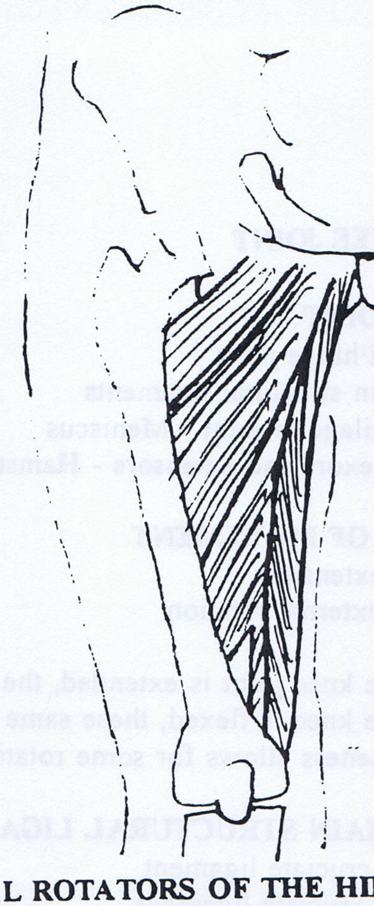
The hip joint provides almost all of the rotation seen in the lower extremity, therefore nearly all of the rotary or steering movement delivered to our skis, is provided by the hip joint.
Due to the size and strength of the muscle groups associated with the hip joint, hip angulation is more active in slower more powerful moves such as those seen in Giant Slalom and Super "G" racing turns.
When the forces in a turn become too great for the knee and ankle to control, we align the osseous structures of the lower extremities (stack the bones) and call on the strength and range of movement of the hip joint and associated muscles to produce the angles required to continue to carve a turn. At extreme speeds we stack the bones of the lower leg, hip and spine to inclinate and thus resist these tremendous forces.

EXTENSORS OF THE HIP
*Most of the muscles situated behind the hip joint i.e. Gluteals, Hamstrings.



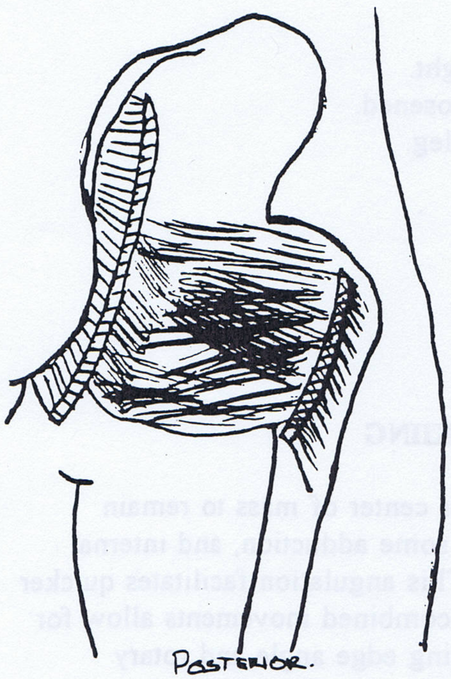
FLEXORS OF THE HIP
*Most of the muscles situated forward (anterior) to the hip joint i.e. Quadriceps.

ABDUCTORS OF THE HIP
*Very inefficient origin and insertion of muscles, lacks leverage to give a strong movement.



ADDUCTORS OF THE HIP

*Far better alignment of muscles with origin and insertion that give better mechanical advantage to create stronger movement. Movements away from the body are weaker than movements towards midline therefore stronger when you create angles under the body not away from the body.

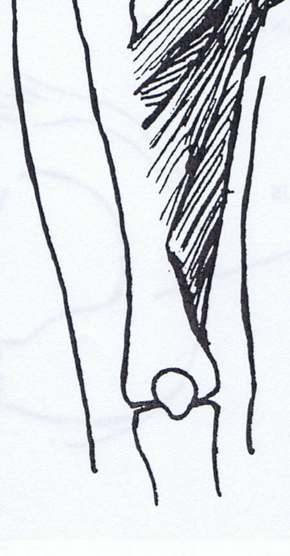


EXTERNAL ROTATORS OF THE HIP

*Though shorter, there is very little leverage, little leverage, hence a weaker move.

MEDIAL ROTATORS OF THE HIP

*More efficient alignment of muscles than external rotators, hence a stronger more precise movement.



THE KNEE JOINT

KNEE JOINT

Modified hinge joint
Four main structural ligaments
Fibrocartilage in joint - Meniscus
Strong flexors and extensors - Hamstrings/Quadriceps

RANGE OF MOVEMENT

Flexion/extension
Internal/external rotation

When the knee joint is extended, the ligaments are tight.
When the knee is flexed, these same ligaments are loosened.
This looseness allows for some rotation in the lower leg.

FOUR MAIN STRUCTURAL LIGAMENTS:

Anterior cruciate ligament
Posterior cruciate ligament
Lateral Colateral ligament
Medial Colateral ligament

THE KNEE JOINT AND ITS IMPORTANCE TO SKIING

Knee flexion combined with ankle flexion, allows our center of mass to remain centered over the foot. Knee flexion combined with some adduction, and internal rotation of the hip, allow for lower leg angulation. This angulation facilitates quicker edge adjustments between ski and snow. The above combined movements allow for us to balance over the outside ski, while still controlling edge angle and rotary movements. It's easier to create angles under the body (towards midline), than it is away from the body. The adductor muscles are strong and better aligned (see diagram).