FICS EXERCISE PHYSIOLOGY - 3

Andrew S Klein, DC, DACBSP, CSCS

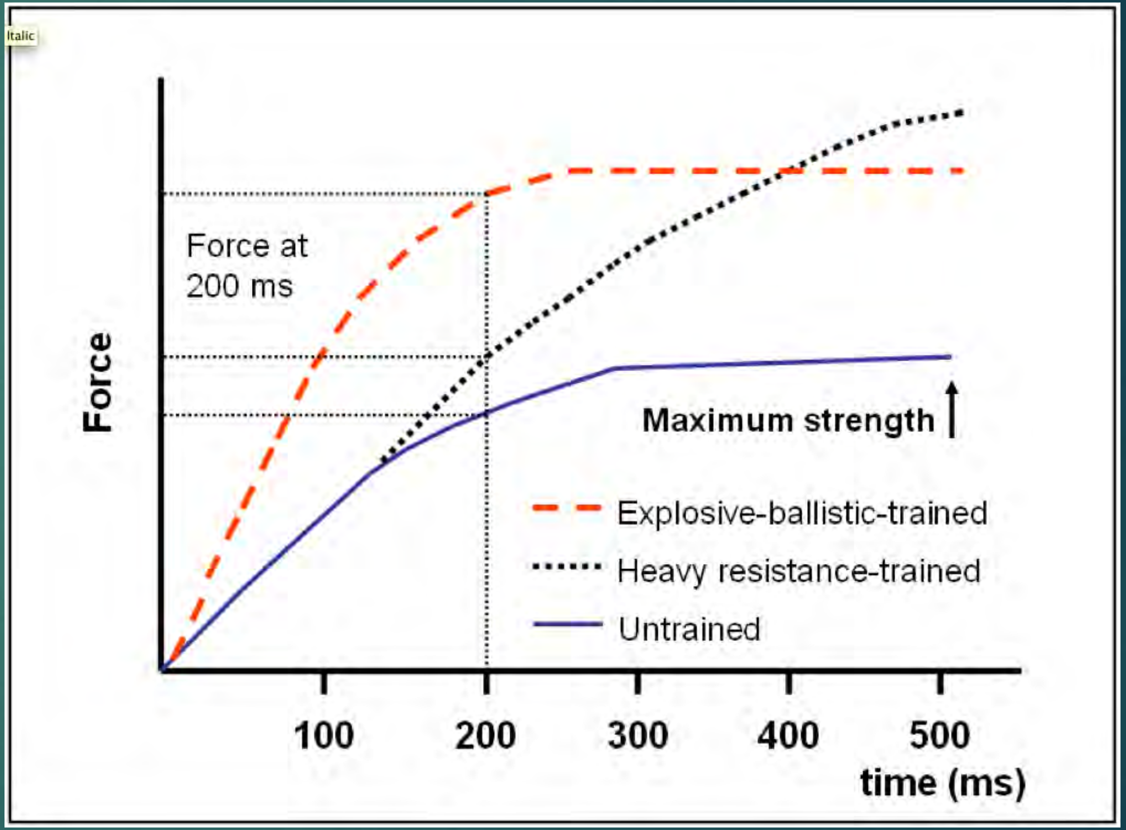
- Speed
- Agility
- Plyometrics
- Program design
- Environmental stresses

- Speed – Ability to achieve high velocity movement
- Change of Direction – Ability to explosively change direction and velocity
- Agility – Ability to change direction and velocity in response to a stimulus

SPEED

- Speed – How fast are you moving
- Velocity – How fast are you moving in a specific direction
- Acceleration – The rate at which velocity changes
- Deceleration – Negative acceleration

Rate of Force Development (RFD) as a function of time.

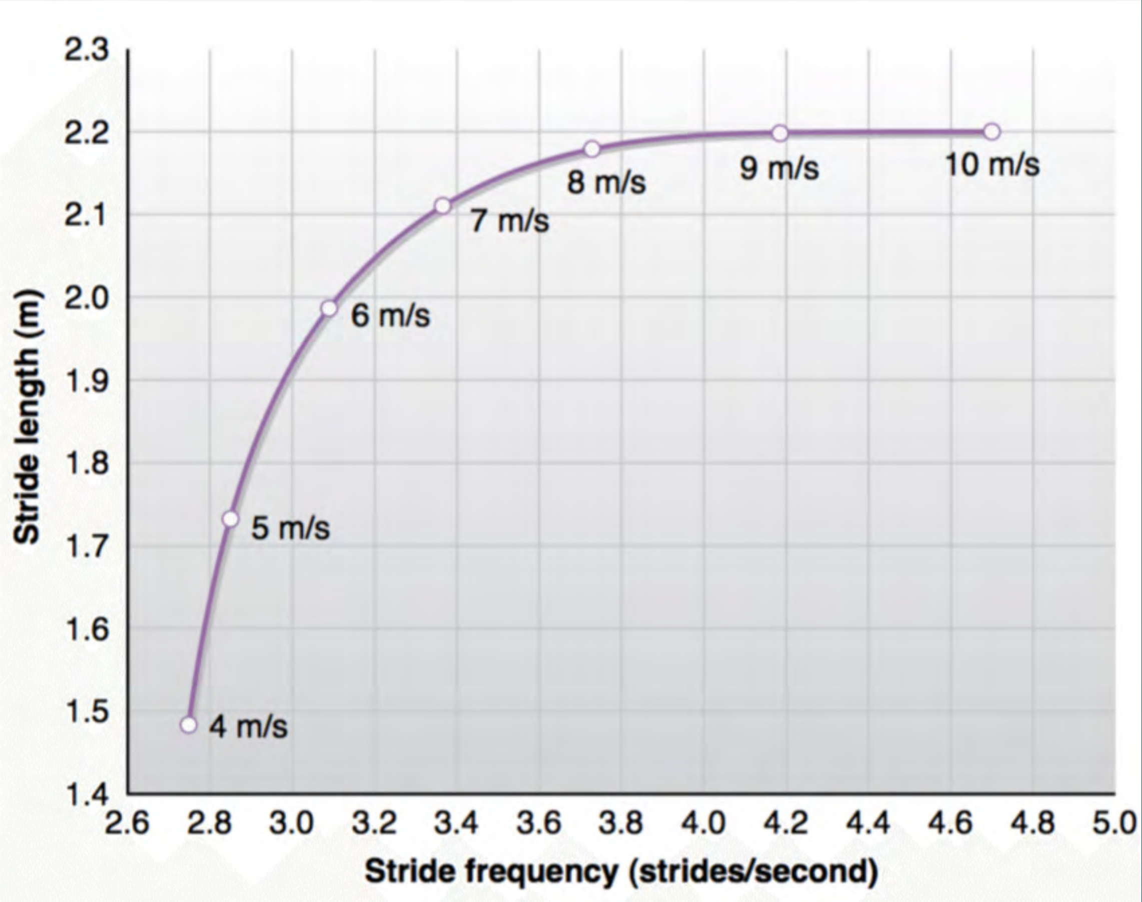


SPEED

- **"Speed is a neural quality "**
  - *Boo Schexnayder*
- Improving neuromuscular integration
  - Improved recruitment
  - Improved rate coding
  - Improved synchronization
- Training the nervous system
  - Quality of work
  - Long rests
  - Low volume

SPEED

- Sprinting involves the relationship between stride frequency and stride length
- Stride frequency– dependent on metabolic systems
- Stride length – biomechanical efficiency
- Neurological efficiency



	Usain Bolt	Other sprinters
Stride Length	2.46 m	2.23 m
Strides in 100 m	40.92	44.91

Sprinting Technique

- Start
  - Out of the blocks or from a stand still position
- Acceleration
  - Initial steps
- Top Speed
  - Also known as maximum velocity

Starting

Starting

- Aggressive extension with both legs
- Vertical forces to overcome a static position in the stance phase
- The current literature suggests that the biggest difference between elite speed and average speed is the amount of vertical force applied to the ground.

SPEED - PHASES OF STRIDE

- Stance Phase
  - Eccentric braking
  - Concentric propulsion
  - Triple Extension– Extending the ankle, knee and hip.

SPEED - PHASES OF STRIDE

- Flight phase
  - Recovery
  - Leg swing for ground preparation
  - Triple Flexion– Flexing the ankle, the knee and hip.

SPEED

- IMPROVING PERFORMANCE
  - Improve strength during the support phase; strength against gravity, propulsive forces
  - Improve swinging actions; speed of circular movements, speed of reversal

SPEED

- IMPROVING PERFORMANCE
  - Strength – weight training, plyometrics, contrast training
  - Contrast training- resistance, assistance

Sled Pulls



Thigh and psoas major muscularity and its relation to running mechanics in sprinters. *Ema R, Sakaguchi M, and Kawakami Y. Med Sci Sports Exerc 2018;50(10):2085-2091.*

Compared with untrained men, sprinters had significantly greater thigh muscle volumes of the hip flexors and extensors, total adductors, gracilis, and psoas major.

Monoarticular knee extensor and flexor thigh muscle volumes were similar between the two groups.

Hip flexion training appear to be more appropriate for sprinters.

Trunk and lower limb muscularity in sprinters: what are the specific muscles for superior sprint performance?

Tottori N, Suga T, Miyake Y, Tsuchikane R, Tanaka T, Terada M, Otsuka M, Nagano A, Fujita S, Isaka T.BMC Res Notes. 2021 Feb 25;14(1):74.

Absolute and relative CSAs of most trunk and lower limb muscles, including the psoas major (PM) and gluteus maximus (GM), were significantly larger in sprinters than in non-sprinters. The absolute and relative CSAs of the PM and GM correlated significantly with personal best 100-m sprint time in sprinters.

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The muscle morphology of elite sprint running.

Miller R, Balshaw TG, Massey GJ, Maeo S, Lanza MB, Johnston M, Allen SJ, Folland JP.Med Sci Sports Exerc. 2021 Apr 1;53(4):804-815.

Investigate the differences in muscle volumes and strength between male elite sprinters, sub-elite sprinters, and untrained controls.

Three hip muscles were consistently larger in elite vs sub-elite (tensor fasciae latae, sartorius, and gluteus maximus. Plantarflexors showed no differences between sprint groups.

Greater hip extensor and gluteus maximus volumes discriminate between elite and sub-elite sprinters and are strongly associated with sprinting performance.

SPEED

- IMPROVING PERFORMANCE
  - TECHNIQUE
  - Leg drills – Triple extension, triple flexion
  - Arm drills – standing and seated
    - Elbows locked, movement at the shoulders
    - **“Chin to Pocket”**

SPEED

- Acceleration
  - 10-40 meters
- Speed (Top End)
  - 40-70 meters
- Speed endurance
  - 80-150 meters

SPEED - STRIDE ANALYSIS

- MUSCLE ENERGY EXPENDED
- 57% to accelerate body segments
- 22% to decelerate body segments
- 3% to balance gravitational forces
- 18% against air resistance and friction

SPEED

- Interaction of stride frequency and stride length
  - Explosive horizontal push-off
  - Minimal vertical displacement

SPEED

- Stance Phase
  - As leg touches down, knee should be slightly flexed at approximately 170 degrees
  - Angle of alignment between toe-hip line and horizontal line is approximately 60-70 degrees

SPEED

- Flight Phase
  - After takeoff, the backward moving leg reaches maximal extension while the front leg is in optimal flexed position
  - When the back leg starts moving forward, the knee flexors should hold the leg folded at approximately 30 degrees
  - Through the propulsion phase, the athlete should bring the foot of the folded leg through the cycle at the same level of the supporting knee

SPEED

- Define what you need to develop.
- Improve strength and power (RFD).
  - Triple extension
  - Triple flexion
- Improve technique
- Emphasize the neural quality of speed.

AGILITY

The ability to change direction rapidly.

1) Anticipated movements (pre-planned).

2) Unanticipated movements in response to an opponent (reactive).

Flexibility

- The ability of a muscle or muscle groups to lengthen passively through a range of motion

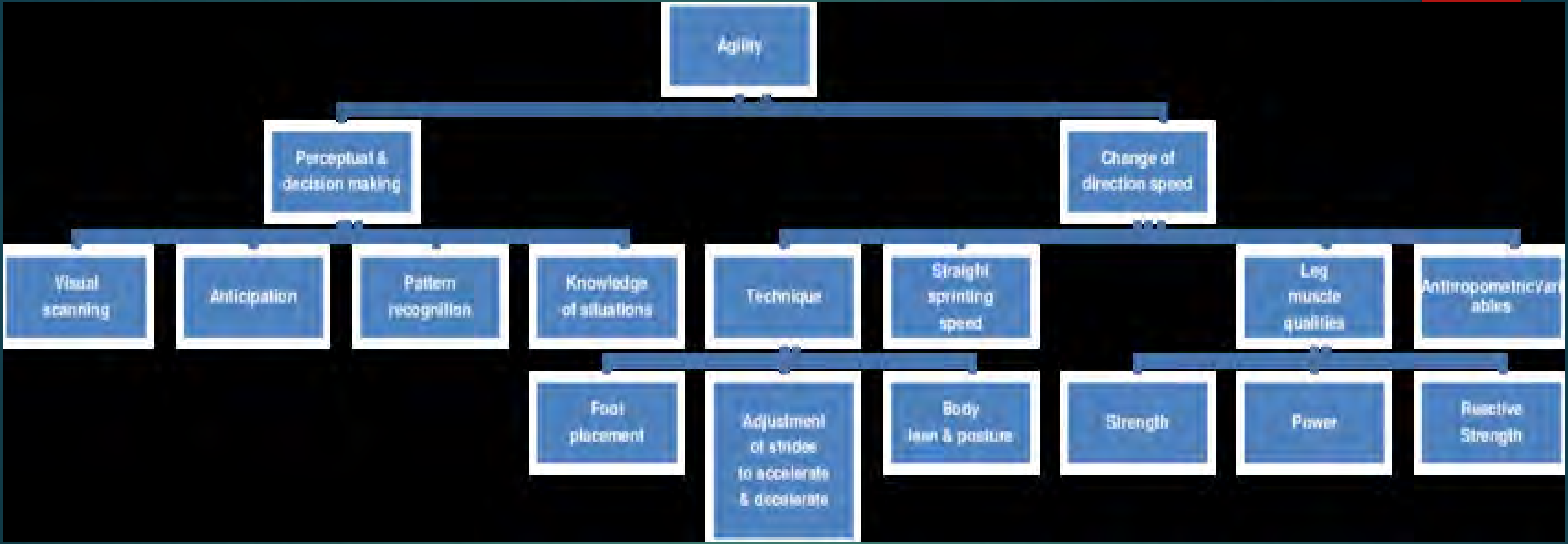
Mobility

- Ability of a joint to move actively through a range of motion

Stiffness

- A measure of how much load a tissue can take before it deforms


#besomebody.

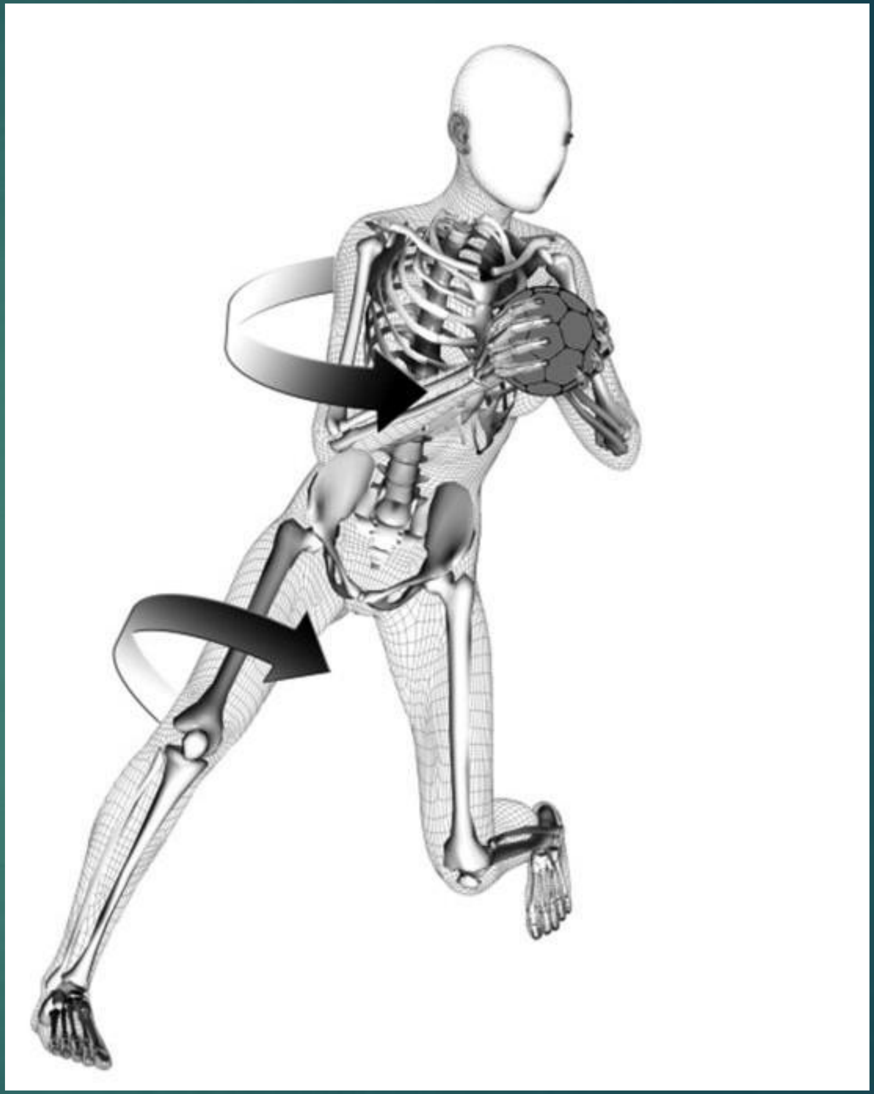


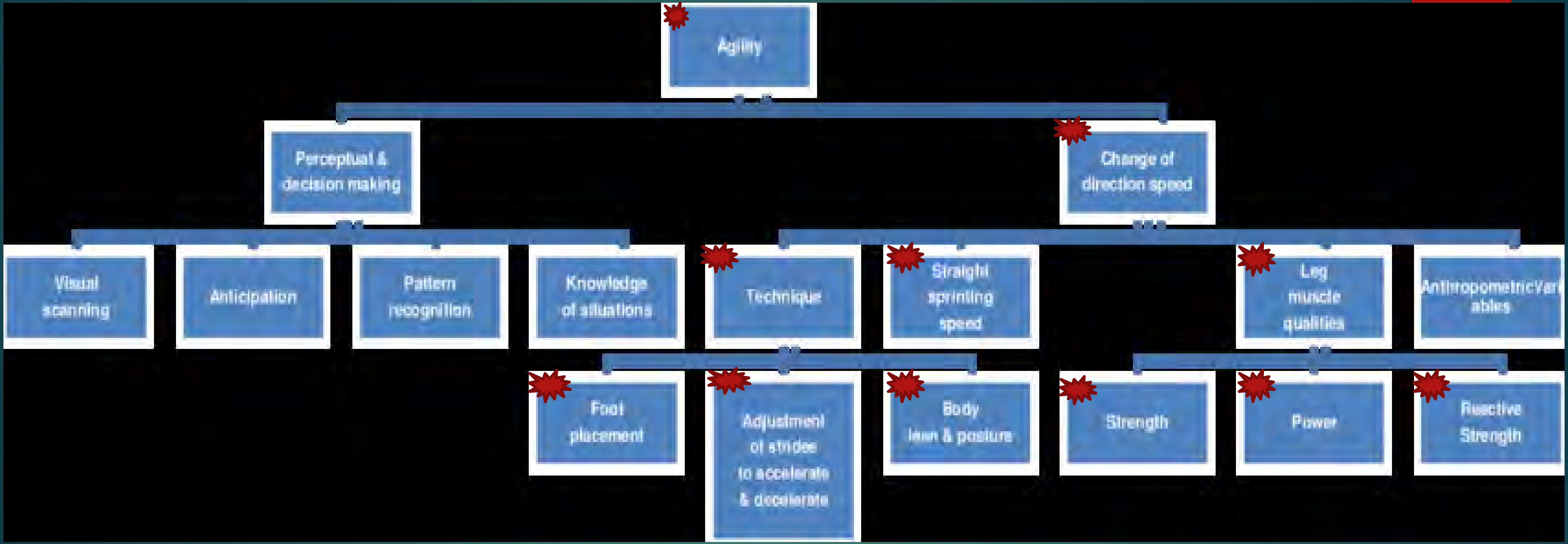
Young WB, James R, Montgomery I.
J Sports Med Phys Fitness. 2002 Sep;42(3):282-8.

Change of Direction

- Shallow cutting angles – shorter ground contact times (<250 ms).
- Aggressive cutting angles – longer ground contact time (>250 ms) – increased deceleration requirements.
- Orientation of the body
- Deceleration to a stop, leading into reacceleration
- Increased muscle mass in combination with decreased % body fat is regarded as a predictor of change of direction ability.

- COM has to be decelerated in the approach and accelerated in the new direction. COM is posterior to the CFA.
- The body then has to be rotated towards the new direction. COM has to be anterior to the CFA.
  - (COM – center of mass)
  - (CFA – center of force application)





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REACTION TIME

Pre-motor time – The time between stimulus identification and the onset of muscle activity.

Motor time – The time between initial muscle activity and initiation of movement. This would include electromechanical delay.

The CNS needs time to identify and implement the appropriate postural and movement strategies.

The muscular system needs the strength necessary for executing the strategies as quickly and efficiently as possible.

Stages of motor learning

- Acquisition – what skills do athletes need to know.
- Application – can the athlete successfully complete the skill.
- Assimilation – can the athlete do the skills and routines automatically.
- Adaptation – can the athlete do the skills and routines automatically in a unique situation.

W drill → reaction drill

Plank Drill – upper body reactive agility

PLYOMETRICS

- Exercises that enable a muscle to reach maximal strength in as short a time as possible. These exercises use the force of gravity to store energy in the elastic components of the muscle and then combine with the energy of the muscular contraction to exert maximal power. Plyometrics has also been called jump training, and stretch-shortening exercises.

PLYOMETRICS

- Depth jump vs Drop jump –

  Dr. Natalia Verkhoshansky

  Paavo Komi – SSC and the drop jump

  Carmelo Bosco – Drop Jump test

PLYOMETRICS

Depth Jumps (Y. Verkhoshansky)

- increase explosive strength
- high drop height (1.10 m)
- pre-landing muscle activation

Drop Jumps (C. Bosco)

- improve elastic energy recoil
- drop height (20-60 cm)

PLYOMETRICS

- If ground contact exceeds 0.25 seconds, then power production can be significantly reduced.

Science for Sport

Table 1. Ground contact times/coupling time of common exercises.

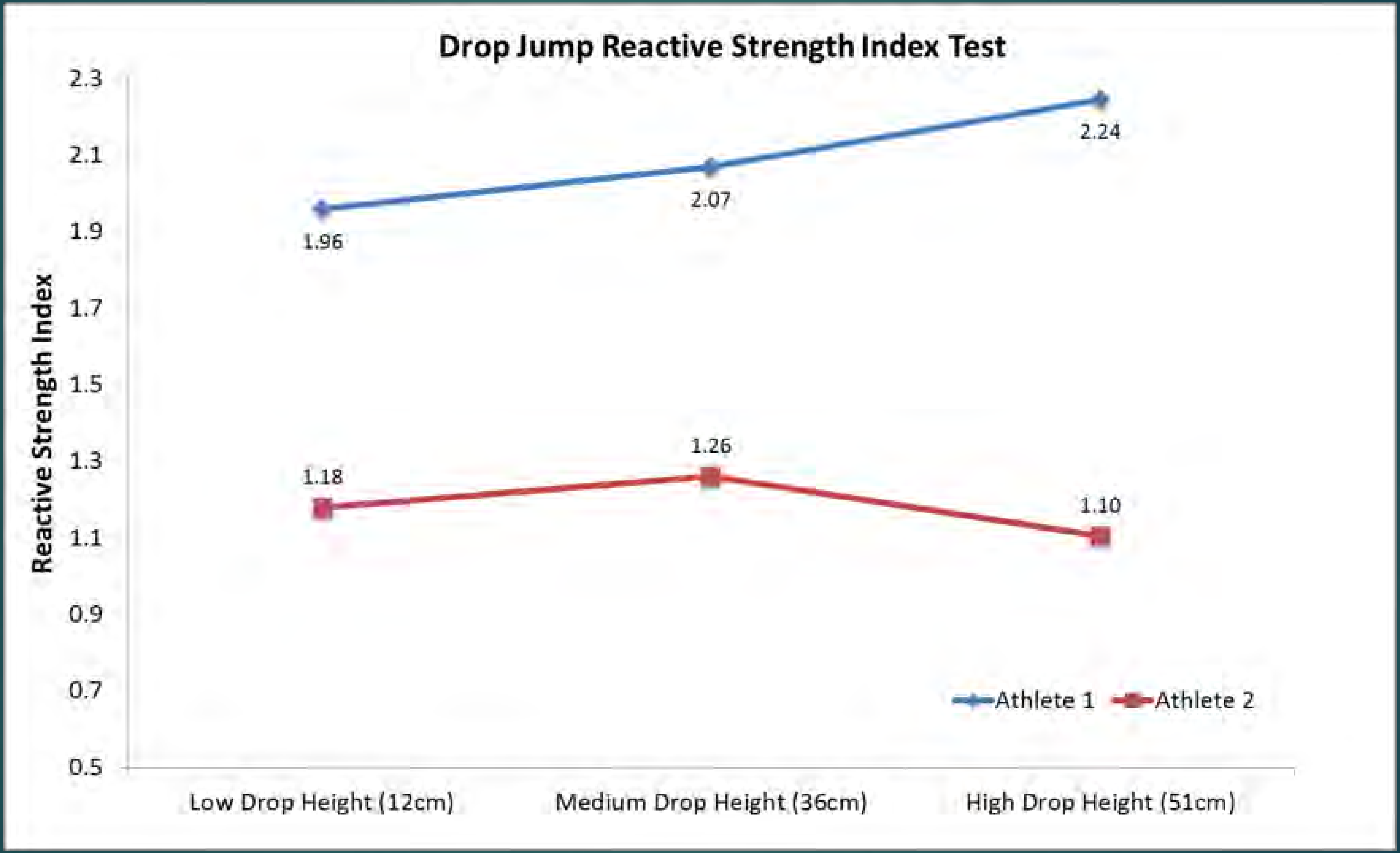
Exercise	Ground Contact Time (Ms)	SSC Classification
Race Walking (18)	270-300	Slow
Sprinting (19)	80-90	Fast
Countermovement Jump (CMJ) (20)	500	Slow
Depth Jump (20cm – 60cm) (16, 17)	130-300	Fast / Slow
Long Jump (21)	140-170	Fast
Multiple Hurdle Jumps (8)	150	Fast

The reactive strength index (RSI) has been developed as a measure of explosive strength and is derived by evaluating jump height divided by ground contact time during the depth jump (DJ).

Reactive strength index (RSI) = Flight Time / Ground Contact Time.

RSI

- <1.5
  - Low reactive strength, strength and low level plyometrics
- 1.5-2.0
  - Moderate reactive strength for plyometrics
- 2.0-2.5
  - Good levels of reactive strength, high intensity plyometrics
- 2.5-3.0
  - High levels of reactive strength, diminishing returns?
- >3.0
  - World class reactive strength ability


Drop Jump Reactive Strength Index Test
Reactive Strength Index
2.3
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
1.96
2.07
2.24
1.18
1.26
1.10
Athlete 1
Athlete 2
Low Drop Height (12cm)
Medium Drop Height (36cm)
High Drop Height (51cm)

- For the muscle spindle reflex to fire, a fast rate of eccentric stretching must occur.
- For elastic energy, there must be a short transition period between eccentric and concentric phases.
- For enhanced motor unit recruitment, there must be a fast eccentric phase and a short transition period between the eccentric and concentric phases.
- For increased force development, the eccentric phase must be slow.

PLYOMETRICS

- Program factors
  - Strength base
    - Lower body – squat 1.5 x body weight
    - Upper body – bench press 1 x body weight

      - 5 clap push-ups
    - Drop heights

      - select drop height as low as 20 cm

      - allow 5 jumps at each height

      - increase the drop height

      - increments of increase should not be greater than 10 cm

PLYOMETRICS

- **If the drop height is too high for the athlete's** strength, ground contact time will increase.

PLYOMETRICS

- There will be bilateral differences in peak force and average force based on drop jump (depth jump) height. Bilateral differences are seen at 20 and 40 cm, but not at a 60 cm starting height.
  - *Ball NB, Stock CG, Scurr JC. JSCR 2010;24(10):2762-2769.*

PLYOMETRICS

- Equipment
  - Footwear
  - Surface
  - Facilities

PLYOMETRICS - Movements

- Jumps – triple extension
- Hops – paw mechanics
- Bounds – push mechanics

PLYOMETRICS

- LEVEL I – Eccentrics

  Landing mechanics – quiet landings

  Minimal flexion at knees and hips

  “Stick it”

PLYOMETRICS

- LEVEL II – Low intensity

  Minimize ground contact – jump height unimportant

  Ankling, skipping, etc.

  Stay on the balls of the feet

PLYOMETRICS

- LEVEL III – Increasing intensity

  Minimizing ground contact and maximizing force, horizontal and/or vertical

PLYOMETRICS

- Jumps in place
- Standing jumps
- Multiple hops/jumps
- Bounds
- Box drills
- Depth jumps

PLYOMETRICS

- Program design
  - Frequency – 2 days of high intensity/wk
  - Volume
    - Beginner 80-100
    - Intermediate 100-120 (100-150)
    - Advanced 120-140 (150-250)
  - Intensity
  - Recovery progressive overload
  - Plyometrics and weight training

PLYOMETRICS

- For children (8-14), current evidence suggests that a program of 2x/week, beginning at 50-60 jumps/session for 8-10 weeks results in the largest changes in running and jumping performance.
  - *Johnson BA, Salzberg CL & Stevenson DA. J Strength Cond Res. 2011:25(9);2623-2633.*

- Plyometric training had a large effect on improving the ability to jump.
- The effects on running velocity were not as consistent across the studies.
- There was also some improvement in agility and kicking distance in soccer players.
- Every study addressed safety in a satisfactory manner.

- Focus of the exercise should be specific to the desired outcome.
- Progression should be to 90-100 jumps by the end of the 10 weeks.
- Sessions should be 10-25 minutes in duration with appropriate warm-up and cool-down.
- Drills should last approx. 10s with 90s rest between drills.
- There should be a low instructor-to-student ration (1:4-5).

PLYOMETRICS

- Sequencing effects of balance and plyometric training on physical performances in youth soccer athletes.
  - *Hammami R, et al., J Strength Cond Res 2016;30(12):3278-3289*

- The objective was to examine the effect of sequencing balance and plyometric training on the performance of 12- to 13-year-old athletes.
- Twenty-four young elite soccer players trained twice per week for 8 weeks either with an initial 4 weeks of balance training followed by 4 weeks of plyometric training (BPT) or 4 weeks of plyometric training followed by 4 weeks of balance training (PBT).

Exercise	Workout 1	Workout 2	Workout 3	Workout 4	Workout 5	Workout 6	Workout 7	Workout 8
Countermovement jump	1 × 8	2 × 10	2 × 12	2 × 15	1 × 10			
Drop jump +1 step	1 × 8	2 × 10	2 × 12	2 × 15	1 × 10			
Horizontal line jump	1 × 8	2 × 10	2 × 12	2 × 15	1 × 10			
Lateral hops	1 × 8	2 × 10	2 × 12	2 × 15	1 × 10			
Ankle jump	1 × 8	2 × 10	2 × 12	2 × 15	1 × 10	3 × 12	3 × 15	1 × 10
Single-leg cone jump: front to back and side to side						3 × 12/leg	3 × 15/leg	1 × 10/leg
Single-leg maximal rebounding: hops +5 m acceleration						3 × 12/leg	3 × 15/leg	1 × 10/leg
Hurdle jump						3 × 12	3 × 15	1 × 10
Drop from a low platform and perform ballistic-type push-ups or clapping push-ups						3 × 12	3 × 15	1 × 10
Total foot/ground contact	40	50	60	75	40	60	75	40

- The major finding of the present study was that sequencing 4 weeks of BPT in 12- to 13-year-old male elite soccer players resulted in either similar or superior performance enhancements compared with plyometric before balance training (PBT).

PROGRAM DESIGN
Needs Analysis

- Needs analysis helps determine the current state of the athlete and what level that athlete wants to achieve.
- Task analysis
- Athlete Analysis
- Goals and Priorities
- Resources and Constraints

PROGRAM DESIGN
Needs Analysis

- SOCCER
  - Less than 2% of total distance is with the ball
  - 1-2,000 bouts of action
  - Activity transition every 5-6 sec, 3 sec rest every 2 minutes
  - Sprints have a 15-meter average, once every 90 sec

PROGRAM DESIGN
Needs Analysis

- SOCCER
  - Standing 17%
  - Walking 40%
  - Easy running 35%
  - Easy running (B) 1.3%
  - Hard running 8%

EXERCISE AND PROGRAM DESIGN TESTING PROTOCOLS

- Administration of tests
  - Supervision
  - Warm-up
  - Motivation
  - Safety

TEST SELECTION

- Local muscular endurance
- Strength / Power
- Aerobic capacity
- Anaerobic capacity
- Agility
- Speed
- Body composition
- Flexibility

TEST SELECTION

- LOCAL MUSCULAR ENDURANCE
  - Curl-ups
  - Push-ups
  - Abdominal endurance
  - Back extensor endurance
  - Lateral trunk endurance

TEST SELECTION

- STRENGTH / POWER
  - 1RM – bench press, squat
  - 1RM – power clean
  - Vertical jump, standing long jump

TEST SELECTION

- AEROBIC CAPACITY
  - 1.5-mile run
  - 12-minute run
- ANAEROBIC CAPACITY
  - 300-yard shuttle

TEST SELECTION

- AGILITY
  - T-test
  - Pro agility test
- SPEED
  - 40-yard sprint

TEST SELECTION

- 40-yard sprint
  - Drive – initial segment lasts 7 steps. Strongest leg forward, weight on opposite hand. Explode out and stay low at 45 degrees. Takes about 1.45 seconds.
  - Transition – Form is the key. Takes about 2 seconds.
  - Finish – **run through the finish and don't lean.** NFL Combine record is John Ross in 2017, 4.22.

TEST SELECTION

- BODY COMPOSITION
  - Hydrostatic weighing *
  - Skin fold and Girth measurements *
  - Bioelectrical Impedance Analysis (BIA) *
  - Near-Infrared Interactance (NIR)
  - Ultrasound, CT, MRI
  - Dual-Energy X-Ray Absorptiometry (DXA) *
  - BOD POD *

TEST SELECTION

- Hydrostatic weighing – Measures the mass per unit of volume. Percentage body fat is estimated based on the density of the body. Residual volume must be accounted for.
- The Siri and Brozek equations are most often used. (Humankinetics.com)

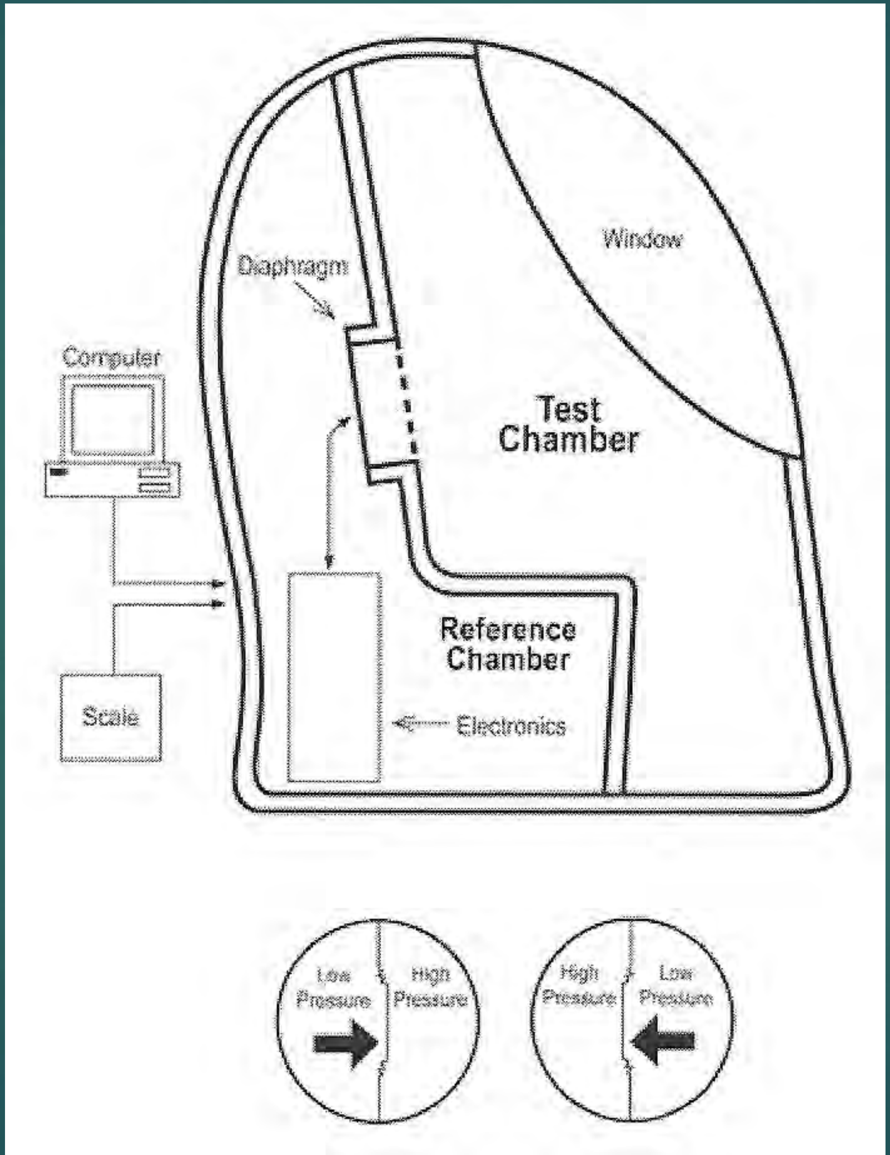
- Hydrostatic weighing may overestimate body fat % of elderly patients suffering from osteoporosis.
- There may be an underestimation of body fat % in athletes due to denser bones and muscles.

- Most body fat estimation techniques are **based on the "two compartment model":** fat, and fat-free mass.
- Fat-free mass includes organs, muscle, bone, and body water.
- Do not equate fat-free mass with muscle.

TEST SELECTION

- Skin fold measurements
  - Based on the relationship between subcutaneous fat and total body fat.
  - A combination of 7 different sites are used; triceps, pectoral, subscapula midaxilla, abdomen, suprailiac, quadriceps.
  - Many different equations to determine body density, ie. Jackson and Pollock.
  - Can be up to 98% accurate.


LANGE SKINFOLD CALIPER
CAMBRIDGE SCIENTIFIC INDUSTRIES
CAMBRIDGE, MARYLAND
MM
0
10
20
30
40
50
60


Diaphragm
Window
Computer
Test Chamber
Reference Chamber
Scale
Electronics
Low Pressure
High Pressure
High Pressure
Low Pressure

TEST SELECTION

- BODY COMPOSITION
- Body Mass Index (BMI)
  - Body mass (kg) / stature (m2)
  - Can be lbs / inches
    - *Underweight = <18.5*
    - *Normal weight = 18.5 – 24.9*
    - *Overweight = 25 – 29.9*
    - *Obesity = BMI of 30 or greater*

TEST SELECTION

- Limitations of BMI
  - It may overestimate body fat in athletes and others who have a muscular build.
  - It may underestimate body fat in older persons and others who have lost muscle.

  - http://www.nhlbisupport.com/bmi

TEST SELECTION

- BODY COMPOSITION
  - Hydrostatic weighing
  - Skinfold measurements
- FLEXIBILITY (or MOBILITY)
  - Sit and reach

TEST SELECTION

- Day 1
  - 2-mile run – under 12 min
- Day 2
  - Shuttle sprint (5-10-15-20-25) – 32sec
  - 60 second sit-up test
  - 60 second push-up test
- Day 3
  - Vertical jump
  - BP (90% max)

Division III soccer

ENVIRONMENTAL STRESSES

- Hypothermia – defined as a condition where the core temp is 95 F (35 C). Muscular coordination becomes affected, and judgment is impaired as core temp decreases.

ENVIRONMENTAL STRESSES

- Wind Chill Index – The wind constantly replaces the insulating air layers around the body with cooler ambient air.

- Respiratory tract – In extreme cold, incoming air is warmed to between 26.5 and 32.2 C by the time it reaches the bronchi.

Altitude Stress

- High altitude – decreased barometric pressure reduces ambient PO2
- Acclimatization – dealing with the reduced loading of HB
- Immediate changes – hyperventilation, increased blood flow from increased submaximum HR
- 2 weeks for 10,000 ft.

Hematological Changes

- Decreased plasma volume
- Increased hematocrit
- Increased hemoglobin
- **Increased # of RBC’s**

Hematological Changes

- Live high-train low model (LHTL) – This model is a training method in which athletes live at high altitude and train at low altitude, usually with the goal of improving performance at sea level. The main idea is to gain the benefits of high altitude acclimatization while maintaining the intensity of low altitude training. Increased EPO activity has been observed. This has not been observed in simulated LHTL conditions (hypoxic tent).

Related Medical Problems

- Acute Mountain Sickness (AMS) – headache, dizziness, nausea, constipation, vomiting visual problems, general weakness. Can occur within 4-12 hrs @ 10,000 feet.
- Appetite suppression can be severe.
- Resolution of symptoms within 1 week.

Related Medical Problems

- High Altitude Pulmonary Edema (HAPE) – general fatigue, coughing, headache, nausea. Occurs in 2% of the population within 12-96 hrs after rapid ascent.
- LIFE THREATENING – The affected person needs to be brought down immediately.

Related Medical Problems

- High Altitude Cerebral Edema (HACE) – more severe than HAPE. Cerebral vasodilation occurs increasing edema that distorts the brain structures. Occurs in 1% of the population.

Related Medical Problems

- 1500 ft. (457 m) – 5% decrease in light sensitivity
- 3000 ft. (914 m) – 25% decrease in light sensitivity
- - 30% decrease in visual acuity
- Denver (1610 m) – 33% decrease in postural stability
- - 15% decrease in cognitive ability
- - 20% decrease in recall ability

THANK YOU!

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