Golf:
Balance as a Function of Vision and Proprioception

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Note to Participants:
There will be interactive questions throughout this lecture. If you choose to 'pause' the lecture, and return at a later time, a natural 'break' time would be after answering the interactive questions. (You are able to pause at any time and the presentation will 'remember' where you were. It's just a more natural time to pause after the interactive questions.) For your convenience, this outline reflects where/when within the lecture the interactive questions occur.

This lecture has 75 slides. It is 70 minutes in duration.

Notes

I. Four Systems for balance
   A. Strength of CORE
      1. Upper leg
      2. Hip
      3. Trunk
   B. Proprioception
      1. Perturbation
   C. Vestibular
      1. Vestibular ocular reflex
   D. Visual
      1. Depth perception and final gaze

II. Rehab and training to enhance performance and protect the knee
   A. Strengthen the quads and hamstrings 80%
      1. Eccentric loading
   B. Reduce anterior shear to the ACL in early rehab 1-3 months
   C. Strengthen the posterior lateral hip
   D. Stabilization exercises for the trunk muscles
   E. Neuromuscular training
      1. Perturbation training
      2. Plyometric exercises (jump training)

III. Posture and position of foot and knee during cutting and landing
   A. Vestibular
      1. Ocular reflex
   B. Vision

IV. Early application of negative work via eccentric ergometry following anterior cruciate ligament reconstruction: a case report. Gerber JP, Marcus RL, Dibble LE, Greis PE, LaStayo PC. J Orthop Sports Phys Ther. 36(5): 2006 May; 298-307
   A. Semi-tendinosus-gracilis autograft initially and then patella-tendon after 2nd tear

B. 3 weeks post-op patient started an eccentric exercise program for 31 weeks over 12 weeks after the repair and 33 sessions after the revision.
C. Quad strength increased 28% while protecting the repair no anterior shear force eccentric loading
D. Return to official Italian First Division soccer games within 90 days after anterior cruciate ligament reconstruction: a case report. Roi GS, Creta D, Nanni G, Marcacci M, Zaffagnini S, Snyder-Mackler L. J Orthop Sports Phys Ther. 35(2): 2005 Feb; 52-61; discussion 61-6
    1. Described a case of an elite soccer player returing to competition 77 days after ACL surgery by using eccentric resistance training program
    2. In 12 weeks quadriceps size and volume increased 28% in the surgically repaired knee
    3. 15 weeks post-surgery the quadriceps strength was 20% greater than pre-operative measures
E. Quadriceps atrophy and strength deficits are the greatest during the first 3 months following ACL repair

V. The physiological effects of eccentric exercise
A. Greatest force production with eccentric loading
B. 75% less oxygen/lower ATP/CP less perceived effort
C. Greater heat production
D. Reduced BP
E. Eccentric training is important to maximizing increases in muscle fiber CSA

VI. Eccentric exercise protects the muscle
A. Repeated bout effect results in protective adaptation to the muscle
    1. Fragile fibers are destroyed after 1st bout stronger fibers survive
B. Sarcomere in series achieved with eccentric training
    1. More resistant to MD by more sacromeres function at short lengths avoiding over-extending the muscles
C. Concentric exercise maybe reduce sarcomeres in series

VII. Preventing muscle loss and injury
A. Saropena
    1. Loss of muscle with aging 15% per decade in 60's and 70's and 30% thereafter
B. Muscle tendon injuries
    1. Increased stiffness of tendon
        a) Greater force to failure and improved ability to absorb energy at the musculo-tendious junction – *Dr. Stanish.* Eccentric kinetic chain exercise as a conservative means of functionally rehabilitating chronic isolated insufficiency of the posterior cruciate ligament

i. MacLean CL, Taunton JE, Clement DB, Regan WD, Stanish WD. Clin J Sport Med. 9(3): 1999 Jul; 142-50

C. Osteopena
   1. Greater loads to bone with higher muscle forces/increased bone mass

D. Reduced falls in elderly
   1. Increased muscle strength of the hip muscles

VIII. Strength of the Quadriceps Femoris muscle and functional recovery after reconstruction of the ACL. A prospective, randomized clinical trial of electrical stimulation. Snyder-Mackler L, Delitto A, Bailey SL, Stralka SW. J Bone Joint Surg Am. 77(8): 1995 Aug; 1166-73

A. Four groups
   1. Early rehab for ACL repair
      a) All groups started intensive CKC
      b) High-intensity ES group, low intensity, Isometric contraction, combined low and high
      c) Quad strength was 70% greater when compared to the uninvolved knee in the high-intensity ES group

B. Improvement in gait was significantly correlated to quad strength

IX. Direct correlation between trunk and hip weakness to LE injury

A. Abdominals
   1. Transverse Abdominus

B. Back extension
   1. Multifidus

C. Quadratus Lumborum
   1. Side bridge

X. Hip ER and abd weakness direct correlation to ACL tears

A. Emphasize posterior fibers of the Gluteus Medius
B. Glut max
C. Hip ER

XI. Balance

A. The ability to position, the ability to voluntarily move and react to perturbation

XII. Four systems for balance

A. Strength
   1. Hip and trunk CORE

B. Prioproception
   1. Neuromuscular training
   2. Perturbation - Plyometrics

C. Vestibular
   1. Vestibular ocular reflex

D. Visual

1. Depth perception and final gaze

XIII. Mechano-receptors
- A. Mechanoreceptors rapidly and slowly adapting receptors
  1. Pacinian rapidly adapting sense sudden movement acceleration or deceleration
  2. Ruffing and Golgi tendo slowly adapting
     a) Sense joint positions
- B. Muscle proprioceptors = muscle spindle
  1. Factors that lead to higher risk for ACL tears
- C. Muscle fatigue and injury alters mechanoreceptor input

XIV. Proprioceptor system
- A. Protective mechanism reflexes between the ligament and the muscle e.g. ACL/hams
- B. Signals the end-range of joint motion facilitating protective reflexes
  1. Training must be performed thru-out the ROM: proprioceptors are activated selectively at specific angles
- C. Muscle receptors
  1. Intermediate & extremes of ROM
- D. Joint receptors more important in extreme ROM

XV. Assessment of neuromuscular system
- A. Special tests
  1. SEBT reach test to predict LE injuries in basketball players
     a) Results: the reliability of the SEBT components ranged from 0.82 to 0.87 (ICC3, I) and was 0.99 for the measurement of limb length
     b) Athletes with anterior right/left reach distance difference greater than 4 cm were 2.5 times more likely to sustain
     c) Incorporated into pre-participation physical examinations to identify basketball players who are at increased risk for injury
     d) Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. J Orthop Sports Phys Ther. 2006 Dec;36(12):911-919
- B. Reach test
  1. Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. Bressel E, Yonker JC, Kras J, Heath EM. J Athl Train.;42(1): 2007 Jan-Mar; 42-6
     a) BESS test
        i. 3 stance positions
           1) Double leg, single leg, tandem
           2) Firm surface and on foam

3) Eyes open and closed
    a. Errors
        i) Opening eyes
        ii) Lifting hands from hip
        iii) Touchdown of non-stance foot
        iv) Step, hop, or other movement on stance foot or feet
        v) Lifting forefoot or heel
        vi) Moving hip into more than 30E flexion or abduction
        vii) Remaining out of position for longer than 5 seconds

XVI. Balance testing of golfers
- A. Limit of stability (LoS) test
- B. Static balance tests
    1. Subject tries to control (minimize) the sway
    2. Test duration 20s, sampling frequency 64Hz
    3. 4 mCTSIB conditions
        a) Rigid surface (normal stability)
            i. Eyes open (NS-EO)
        b) Rigid surface (normal stability)
            i. Eyes closed (NS-EC)
        c) Foam cushion (perturbed stability)
            i. Eyes open (PS-EO)
        d) Foam cushion (perturbed stability)
            i. Eye closed (PS-EC)
    4. 4 “golf” single leg stance (SLS) conditions
        a) Dominant leg
            i. Eyes closed (D-EC)
        b) Non-dominant leg
            i. Eyes closed (ND-EC)
        c) Take away
            i. Eyes open (TA-EO)
        d) Follow through
            i. Eyes open (FT-EO)
    5. Parameters considered
        a) Stability score: ratio between 95% confidence sway (major semi-axis of ellipse) and theoretical LoS, with 100% being no sway and 0% being sway >= theoretical LoS
        b) Several other parameters calculated but not yet analyzed
- C. Limit of stability (LoS) results
- D. mCTSIB static balance results
- E. SLS static balance results
- F. Balance testing conclusions
    1. Subjects seem to have better then normal performance in the most common situations

2. However subjects have unexpected weakness in some less common situations:
    a) Backward LoS
    b) Perturbed surface mCTSIB tests
    c) Single leg stance
3. It is reasonable to expect that those weakness affect their game, especially the SLS weakness
4. As subjects have otherwise better than normal results, it is also reasonable to expect that with the proper intervention/training they should be able to resolve their weaknesses
5. The use of advanced balance assessment instruments like the CAPS™ professional system allows to easily identify the weaknesses and track the progress towards eliminating them

XVII. Neuromuscular training ACL prevention
- A. Proprioceptive training in rehab of knee stability in soccer players
- B. *Rusu et al Sports Med & Kynesiology Un. Craiova, Romania*
- C. 15 soccer players
    1. All players had improvements of mobility and stability
- D. Lachman test and valgus stress test demonstrated significant improvement

XVIII. Training the neuromuscular system proprioception
- A. Prevention of injuries in young female players in European team handball. A prospective intervention study. Wedderkopp N, Kaltoft M, Lundgaard B, Rosendahl M, Froberg K. Scand J Med Sci Sports. 9(1): 1999 Feb; 41-7
- B. 237 handball players female 10-15 min training 10 months
    1. Control group 5.6x greater chance of injury
- C. Training using balance board
    1. Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training. Caraffa A, Cerulli G, Projetti M, Aisa G, Rizzo A. Knee Surg Sports Traumatol Arthrosc. 4(1): 1996; 19-21
        a) 600 soccer/3 seasons 300 trained traditional
        b) 300 proprioceptive training
        c) 70 ACL tears traditional and 10 ACL tears balance group

XIX. Perturbation training
- A. The efficacy of perturbation training in nonoperative anterior cruciate ligament rehabilitation programs for physical active individuals. Fitzgerald GK, Axe MJ, Snyder-Mackler L. Phys Ther. 80(2): 2000 Feb; 128-40
- B. Perturbation group 5x more likely to return to high level physical activity than the standard training
- C. Training

1. 20 minutes per day
2. 5 levels of difficulty
3. Each phase of training 3-6 days
4. All training sessions lasted 30 days
5. Use of balance boards and wobble boards

D. *Johansson* suggested by stimulation of mechanoreceptors increase gamma motor activity increasing muscle spindle sensitivity. Thus, higher state of readiness of muscles to respond to perturbing force applied to the joint improving stability by reacting quickly to unexpected movements such as quick turns

E. Perturbation training
   1. Swiss ball kneeling
   2. Standing swiss ball/squat
   3. Perturbation program
   4. Shuttle balance
      a) Bob Donatelli

F. Beginner phase
   1. Standing both feet while throwing medicine ball against Plyoback and/or another person
   2. Standing both feet while perturbing the balance board
   3. Single leg stance while throwing a medicine ball
   4. Overhead into plyoback
   5. Rotation into plyoback
   6. Single leg stance while eyes closed/blindfolded
   7. Single leg stance unstable surface
   8. Perturbation
   9. Perturbation program
   10. Shuttle balance
      a) Bob Donatelli

G. Intermediate phase – firm to softer foam
   1. Single leg stance on foam pad
   2. Single leg stance on foam pad while throwing medicine ball
   3. Single leg stance on foam pad while performing toe raises
   4. Single leg stance on foam pad while kicking against the resistance of theraband
   5. Single leg stance on foam while swinging a bat, golf club, tennis racket or hockey stick
   6. Perturbation beginner
   7. Perturbation program
   8. Shuttle balance
      a) Bob Donatelli

H. Advanced phase level 1 – jumping on to the board
   1. Jump onto the balance and hold for 5-6 seconds
   2. Jump onto the foam pad on the balance board and maintain balance 5-6 seconds

3. Jump onto the foam pad on the balance board, hold 5-6 seconds, then jump off onto a foam pad on the floor, holding long enough to catch a medicine ball, throw over athletes head
4. Jump on foam pad on the balance board, hold 5-6 seconds and switch feet, jumping onto the opposite foot
5. Jump onto the foam pad, switch feet two-three times and then jump off onto a foam pad on the floor
6. Single leg stance jumping on to unstable board
7. Perturbation program
8. Shuttle balance
    a) Bob Donatelli

I. Advanced phase level 2 – while jumping onto the BOSU ball on the balance board
    1. Jump onto the BOSU ball on the balance board, hold balance for 4-5 seconds and catch a medicine ball and/or soccer ball, baseball, hit a tennis ball, etc
    2. Jump onto the BOSU ball on the balance board, hold 4-5 seconds and switch feet
        a) R-L-R-L
    3. Jump onto the BOSU ball on the balance board, hold 4-5 seconds and jump off onto a foam pad on the floor
    4. Balance on the BOSU ball on the balance board both feet, while performing sports specific activities, such as shooting basketball, throwing soccer ball overhead, swing baseball bat, throw/catch football, etc
    5. Advanced training jumping on to the unstable surface

Interactive Questions – slide 45 @ 41 minutes

XX. Plyometrics training
- A. Stretch reflex or myotactic
    1. Intrafusal fibers/muscle spindle respond to the rate at which the muscle is stretched
- B. Stronger muscle contraction to reduce the stretch
- C. Stretch shortening cycle
    1. Rapid deceleration followed by an immediate rapid acceleration

XXI. Plyometrics prerequisites
- A. Strength base
    1. Poer squat 60% body wt
        a) Good hip strength
- B. One leg half squat
    1. Balance and quad strength
- C. Stork balance test eyes open/closed
- D. Good quad strength MMT
- E. No patella femoral pain/poor alignment
- F. Good landing surface/shoes
- G. No acute injuries to the foot or ankle

XXII. Types of plyometrics
- A. Natural plyometrics
  1. Hopping, jumping
- B. Depth jumping
  1. Only for specific athletes 220 lbs no higher than 18 inches
- C. Low intensity
  1. Skipping drills, 8 inch cone hops
  2. Lateral bounding
  3. Shuttle 200

XXIII. Plyometric training
- A. 48-72 hours recovery
- B. 2x per week
- C. 60-90 seconds per exercise
- D. 50-100 seconds rest

XXIV. Plyometric training in female athletes
- A. Plyometric training in female athletes. Decreased impact forces and increased hamstring torques. Hewett TE, Stroupe AL, Nance TA, Noyes FR. Am J Sports Med. 24(6): 1996 Nov-Dec; 765-73
  1. Purpose
     a) Effects of jump training on landing mechanics and lower extremity muscle strength in female athletes involved in a jumping sport
  2. Results
     a) Program was designed to decrease landing forces by teaching neuromuscular control of the LE during landing and to increase vertical jump
     b) After training peak landing forces dec, 22% and knee add &abd moments dec. 50%
     c) Hamstring power inc. 44%peak torque ratio hams/quad inc. 13%

XXV. Plyometrics and balance
- A. Plyometric drills sports specific

XXVI. Balance Bob – this is a repeat – is this what you want?
- A. The ability to maintain position, the ability to voluntarily move and react to perturbation

Interactive Questions – slide 64 @ 58 minutes

XXVII. Four systems for balance
- A. Strength
  1. Hip and trunk CORE
- B. Prioproception
  1. Neuromuscular training
  2. Perturbation - Plyometrics
- C. Vestibular

1. vestibular ocular reflex

D. Visual
   1. Depth perception and final gaze

XXVIII. Vestibular system
A. Vestibular system detects motion of the head and maintains stability of images on the fovea of the retina as well as postural control during head motion
B. Vestibular receptors in the inner ear can provide an exquisitely accurate representation of head motion in 3 dimensions
C. Running can have head velocities of up to 550°/sec, head accelerations of up to 6000°/sec

XXIX. Head thrust test for identifying vestibular hypofunction
A. Normal head thrust A-B
   1. A-initial starting position eyes are focused on a target cervical flexion
   2. B-turning to the left upon stopping the head turn eyes are still on target
B. Abnormal head thrust C-E
   1. C-initial starting position
   2. D-turned to right eyes are not on target
   3. E-eyes make a correction bring eyes back to target
C. Smooth pursuit
   1. Head still
   2. Eyes follow target through 20-40 deg/sec through narrow arc
   3. Unable to maintain image on retina over 150° sec=15mph
   4. Looking for nystagmus
   5. Deteriorates with age
   6. Detects spins of an object, acceleration or decreases in speed
D. Saccades
   1. Head still
   2. Ballistic eye movements reach speeds excess of 900-1000°/sec =90 mph (145 kph)
      a) Important for high velocity objects such as in baseball, hockey puck, tennis ball, lacrosse, handball etc
E. Dynamic visual acuity
   1. Head moves
   2. Eyes on target
   3. 1 Hz combo VOR & COR
   4. 3 Hz purely VOR
   5. Can qualify with eye chart
   6. Up to 2 line changes (i.e. 20/20 →20/50) is WNL

7. Computerized dynamic visual acuity test in the assessment of vestibular deficits. Herdman SJ, Tusa RJ, Blatt P, Suzuki A, Venuto PJ, Roberts D. Am J Otol. 19(6): 1998 Nov; 790-6

XXX. Perturbation program
- A. Shuttle balance
  1. Bob Donatelli
- B. Advanced phase level 3
  1. Vestibular exercise with balance board
     - a) While balancing on the board with both feet and then progressing to one foot:
       - i. Eyes on an object with head turns from side to side
       - ii. Head turns up and down
       - iii. Head turns diagonal
     - b) To help visual activity
       - i. Use a large letter and progress to smaller letter. Ask athlete if object is blurry while they move head and maintain balance on the board.
     - c) The foam pad, BOSU ball and the different level of balance difficulty can be used to challenge the athlete

XXXI. Vestibular system
- A. Blind fold
  1. Smooth pursuit, visual activity, saccades

XXXII. Balance
- A. The ability to maintain position, the ability to voluntarily move and react to perturbation

XXXIII. Four systems for balance
- A. Strength
  1. Hip and trunk CORE
- B. Proprioception
  1. Neuromuscular training
  2. Perturbation - Plyometrics
- C. Vestibular
  1. Vestibular ocular reflex
- D. Visual
  1. Depth perception & final gaze

XXXIV. What does the athlete see?
- A. Fred Funk looks from the tee to the flag
- B. He uses visual feedback to adjust his spatial awareness via gaze control to abstract targets:
  1. Putting on a sloped green
- C. Like all predatory mammals he is judging distance to his prey (in this case a small hole) using binocular vision

D. Instead of judging when to pounce he will select the correct club and how to hit it
    1. See Fred take away
E. Fred addresses with a quiet eye
F. Slowly moves to take away & maintain quiet eye on the ball visual target is behind the ball or on top
G. Head rotation requires an effective VOR helps to maintain quiet eye
    1. Begins before the backswing & maintained until after ball contact
H. Maintaining dynamic visual activity
    1. See Fred impact
    2. Using binocular vision perceives the exact distance the ball is to the club
    3. Quiet eye maintains object on the fovea directly after ball contact saccades & visual pursuit allows him to follow the ball

XXXV. Theoretical VOR in swing
A. Take away→Address→Follow Through
B. See Fred impact
    1. Uses saccade to locate rapidly moving ball
C. See Fred follow through
    1. Smooth visual pursuit tracks ball to ground
    2. Provides visual feedback on shot
    3. Helps preview next lie
    4. Prevents anxiety in amateurs

XXXVI. Vision and putting for the elite golfer
A. Fixation of the hole
    1. Longer and uses slow
    2. Saccades of about 500 ms between the hole and ball
B. Directed 2-3 fixations to the hole and ball or club, with saccades linking the fixations
C. During the stroke maintained quiet eye on the top or back of the ball thru the back swing and forward swing
D. At contact the quiet eye remained on the putting surface for 250ms

XXXVII. Location of gaze
A. Top or behind the ball

XXXVIII. Summary
A. Rehab of ACL, PALm meniscus Surgery, Ankle Injuries
    1. First 4 weeks use of high frequency stimulation to the quads/hamstrings
    2. Eccentric loading to the quad/hamstrings starting 3 weeks post-surgery
    3. Strengthening exercise emphasizing eccentric loading to the posterior hip muscles

    a) Posterior fibers of gluteus medius, gluteus maximus, ER
4. Endurance exercises to the trunk
    a) Quadratus, extensors, abdominals
5. Neuromuscular training
    a) Perturbation
    b) Vestibular
    c) Bi-ocular vision
    d) Quiet eye
6. Plyometrics
    a) When strength has normal

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