Assessment, Movement Analysis, and Injury Prevention for the elite volleyball athlete: Can you dig it?

Introduction
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1. Introduction to Volleyball
   a. Invented in the U.S. by William G. Morgan in 1895 at YMCA
   b. Played by over 200 million people worldwide
   c. Combines UE and LE quickness, power, and endurance
   d. Due to sport demands, high injury risk, especially in skeletally immature athletes
   e. Indoor
      i. 6 players on floor (3 front row, 3 back row)
      ii. Olympics 1924 as demonstration event
      iii. 1964 first year as official sport
      iv. Court:
         1. Dimensions: 9 meters x 19 meters (29.5’ x 59.1’)
            a. Attack line: 3 m from net
         2. Net: 7’11 11/16” men and 7’ 4 3/16” women
      v. Players must rotate clockwise once serve is gained
      vi. Must return within 3 hits; initial block not counted
      vii. Players
          1. Libero, Setters, Middle Hitters, Outside Hitters, Opposite Hitters
   f. Beach
      i. 2 players on sand
      ii. Olympics 1996
      iii. Court:
           1. 8 m or 26.2’ square
           2. Net Height: identical to indoor
      iv. Scoring
           1. Typical: first to 21 points per set; best of 5 sets
              a. Deciding set up to 15
           2. Switch ends every 7 points (every 5 on deciding set)
   g. Serves
      1. Average serve: 80mph fastest
      2. 3 Types
         a. Standing
         b. Jump Float
         c. Power Jump
   h. Spike
1. Must be contacted on own side of net but may follow through over net
2. Back line players may not make contact when ball is above net
3. Speed (males)
   a. 70-80mph in Olympics
   b. 50-60mph in Collegiate
   c. 40-50mph in HS
i. Block
   1. Team ending with ball may hit 3 additional times
   2. Blocking player may make first hit after block
j. Participation
   i. HS 2014-15¹
      1. Boys: 54,418
      2. Girls: 432,176
         a. Second to TF
   ii. NCAA 2014-2015
      1. Women: 17,026
      2. Men’s: 1,818
2. Epidemiology
   a. 12 ED visits per 100,000 hours (avg across sport = 7.6)³
   b. Overall 1.7 – 10.7 injuries per 1000 hrs.
      i. Match: 2.6-4.1/1000 hrs. ; Practice 1.5-1.8/1000 hrs.
      ii. Ankle: 0.9-1.0; Knee 0.3 ; Shoulder 0.2/1000 hrs.
3. Differential Diagnosis
   a. Acute vs Chronic
   b. Age specific pathology
   c. Upper Extremity
      i. Shoulder and fingers most common
   d. Lower Extremity
      i. Slight Majority of injuries
      ii. Ankle most common
4. Injury Patterns
   a. Gender Differences
      i. Female > Male
   b. Movement Patterns
   c. Contact vs Non-contact
   d. Position Specific  - front row more often injured than back row

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Biomechanics of the Volleyball Attack and Serve
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I. Introduction
a. Variation in technique
   i. Position
   ii. Athletic ability
   iii. Skill level
   iv. Indoor vs. beach play
   v. Defense alignment

b. Limitations in research

II. Athleticism and skill
a. Elite
   i. Advanced physical abilities
      1. Vertical and horizontal jump
      2. Visual tracking
      3. Kinetic chain coordination
   ii. Consistent and advanced skill level
      1. Ball contact position
      2. Rapid arm swing

b. Intermediate
   i. Physical abilities not developed
   ii. Less consistent skill performance

c. Beginner
   i. Poor physical abilities
      1. May not be able to strike ball above net
      2. Less horizontal distance covered during approach
      3. Limited trunk contributions to arm power
   ii. Inconsistent skill performance
      1. Ball strike position does not permit optimum transfer of energy
      2. Slower arm swing

d. Impact on injury risk

III. Phases and events of attack

*Figure from:* Reeser JC et al: Upper Limb Biomechanics During the Volleyball Serve and Spike. Sports Health 2010.
IV. Kinematics and kinetics
   a. Cross body spike, straight ahead spike and jump serve with similar kinetic values
      i. Lower values for float serve and roll shot
      ii. Impact of slower arm speed
   b. Maximum shoulder IR torque and elbow varus torque produced near time of maximum shoulder ER
      Role in arm deceleration
   c. Maximum proximal forces produced at end of arm acceleration phase
      Role in resisting joint distraction
   d. Float serve and roll shot associated with lower joint velocities and ball speed
   e. Similar kinematics for cross body, straight ahead spike and jump serve
   f. Comparative biomechanics
      i. Lower forces and torques at shoulder and elbow than female pitchers and tennis players
      ii. Limitations in methodology
   g. Clinical impact
      i. Guides motion and strength demands of sport
      ii. Return to sport after UE injury may include greater number of low demand arm swings (roll shot, float serve)

V. Muscle activity (anterior deltoid, supraspinatus, infraspinatus, teres minor, subscapularis, teres major, latissimus dorsi, pectoralis major)
   a. Wind up/approach
      i. Serve
         Relatively low activity during serve
      ii. Attack
         1. Synergistic action of anterior deltoid and supraspinatus to position humerus overhead
         2. Infraspinatus and teres minor act to position humeral head within glenoid fossa
   b. Cocking
      i. Serve
         1. Humerus remains elevated with horizontal extension and maximum external rotation of the shoulder
         2. Increase in activity for inner (subscapularis and teres major) and outer (latissimus dorsi and pectoralis major) anterior wall muscles may be secondary to their protective role against anterior subluxation
      ii. Attack
         1. Supraspinatus and anterior deltoid continue to work to maintain humeral elevation
2. Infraspinatus and teres minor function to achieve shoulder external rotation

c. Acceleration
   i. Serve
      1. Float serve acceleration is comparatively slower
         Placement is objective
      2. Peak teres minor activity as it functioned to restrain anterior humeral translation
      3. Anterior wall muscles acting to internally rotate and adduct humerus
   ii. Attack
      1. Maximum force generation is objective
      2. Less anterior deltoid and supraspinatus activity as arm is moving into extension
      3. Teres minor limiting anterior humeral translation
      4. Peak anterior wall muscle activity

d. Deceleration/follow through
   i. Serve
      1. More limited follow through with float serve
      2. Anterior deltoid and supraspinatus control humerus extension
      3. Infraspinatus and teres minor act to compress humeral head in glenoid fossa
      4. Minimal anterior wall muscle activity
   ii. Attack
      1. Kinetic energy dissipation distributed across deceleration and follow through
      2. Humerus did not remain elevated, resulting in relatively low anterior deltoid and supraspinatus activity
      3. Infraspinatus and teres minor playing stabilizing role
      4. Lower anterior wall muscle activity

VI. Jump biomechanics
   a. Deep knee flexion with take-off and landing
      Combined with high volume may contribute to Jumper’s Knee
   b. Often single leg or off balanced landing
      May lead to acute injury, including ankle sprain and knee ligament/meniscus injuries
   c. Dynamic valgus collapse observed in faulty jump mechanics
      Associated with PF syndrome and ACL injury risk

VII. Conclusions
Evaluation and Screening of the Volleyball Athlete
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I. Pre-injury screening

1. Pre-participation movement screens widely used to assess musculoskeletal injury risk
2. Only 2 have established validity and reliability:
   a. Functional Movement Screen (FMS)
      i. Good inter-rater and test-retest reliability (kappa = 0.74-1.0, ICC = 0.92 – 0.98)
      ii. Developers have cautioned against using the FMS to predict injury risk; “this was not the screen’s intent”
      iii. Conflicting evidence surrounding the predictive validity of the FMS screen
      iv. Composite score shows low internal consistency and inconsistent factor loading was demonstrated within the 7 tasks across a number of different populations
      v. Minimal focus on UE and core
   b. Nine Test Screen Battery (9TSB) aim to identify functional movement limitations in athletes; more focus on core vs. FMS
      i. Good inter-rater reliability (ICC = 0.80)
      ii. No evidence of predictive validity to date.
      iii. Conflicting reports revealed the presences of 2-4 underlying constructs (e.g. overall physical function) without the ability to assess unique constructs
3. Is injury- AND sport-specific screening is a better option?
   a. Design with respect to common injuries (epidemiology)

4. Screening for ACL/LE Risk
   a. Drop jump assessment: Landing Error Scoring System (LESS)
   b. Developed as a tool that can be applied to identify individuals who display at-risk movement patterns during the drop vertical jump test
   c. Established reliability
   d. Some evidence supports that LESS showed predictive validity in identifying ACL injuries, however only in a youth athlete population
   e. Other field tests:
      i. Tuck jump assessment
ii. Excellent intra- and inter-rate reliability
iii. Specific to ACL risk
f. Observational Screening of Dynamic Knee Valgus (OSDKV)
g. Y-Balance test

5. Are clinical assessments adequate?

6. **Upper extremity injury screening**
   a. Postural assessment
      i. SICK scapula; infraspinatus atrophy
   b. ROM asymmetry known to exist
      i. Adaptive versus pathological
   c. Strength asymmetry also known to exist
      i. How much symmetry is expected?
   d. Upper extremity functional testing
      i. Normative values established for collegiate VB athletes
      ii. No UE functional test has shown to be predictive of injury in this population
      iii. HOWEVER; bilateral tests can be compared to norms for performance,
           unilateral tests for symmetry

7. **Assessment of core stability**
   a. Muscle capacity *versus* neuromuscular control
   b. Common clinical tests:
      i. DLLT
      ii. Flexor, extensor, side plank endurance tests
      iii. Unilateral hip bridge endurance test

8. What are we missing with clinical core assessments?

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**Injury Prevention**
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1. Jump Landing Mechanics
   a. Block Jump Task – Cuing to increase knee flexion and to “land softly”
      significantly increased knee flexion angle and significantly reduced ground
   b. Improving the knee flexion angle to greater than 30 degrees is helpful in reducing
      ACL injuries during block jump landing in volleyball. Reverse and Go landings
      may be most dangerous (Zahradnik D, Jandacka D, Farana R, Uchytil J &Hamill J
   c. Improving the athlete’s lower extremity contact angle during jump landing to
      reduce deceleration forces (Kulig K, Noceti-DeWitt LM, Reischl SF, Landel RF,
      *Braz J Phys Ther* 2015)
d. Smaller knee flexion moments and increased vertical ground reaction forces are associated with increased knee injuries (van der Does HTD et al. *Int J Sports Med* 2016)

2. Proper Jump Form (Jump Training)
   a. 12-month training program looking at the strength power and anthropometric measurements of 20 elite volleyball players demonstrate a high correlation between improvements in the counter movement jump squat, and the spike jump with improvements in the peak velocity and relative power in the loaded jump squat. (Sheppard JM et al. *J Strength Cond Res*, 2009)

3. Sports Specific Core Stability Program
      i. Phase 1 – Low-velocity motor control, kinesthetic awareness and endurance in neutral spine
      ii. Phase 2 – Progressive increase in multiplanar endurance, coordination and strength integrating upper and lower extremities maintaining neutral spine
      iii. Phase 3 – Volleyball specific skill integration during dynamic tasks

4. Upper Extremity Biomechanics and Injury Prevention
   a. Kinematic data suggest that the highest forces, torques and angular velocities at the shoulder occur during spiking activity (Reeser JC. *Sports Health* 2010)
   b. Shoulder abduction values at ball contact for a variety of skills have been measured at 130 degrees or more. (Reeser JC. *Sports Health*. 2010)
   c. Asymmetrical shoulder ER/IR strength ratios have been studied in elite level male and female volleyball players, specifically on their dominant side (Hadzic VH et al. *J Athl Train*. 2014)

5. Prevention of Acute Ankle Injuries
   a. Landing techniques with increased ankle dorsiflexion moments are associated with reduced ankle injuries
References


