Neuromuscular Training & ACL Injury Prevention: A Systematic Review

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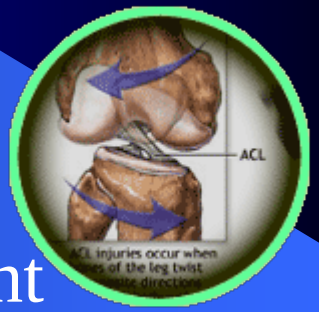


Outline

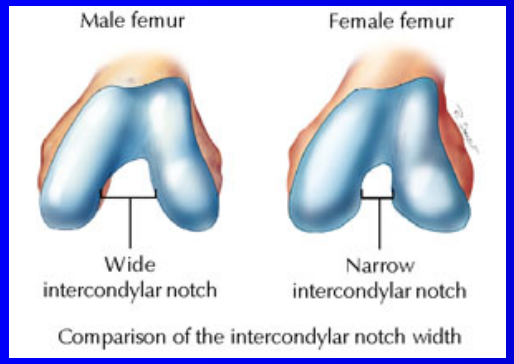
- Introduction to ACL injuries
- Purpose of our review
- Method
- Results
- Discussion
- Conclusions
- Questions

An Introduction to ACL Injuries

- ~70% are non-contact (Arendt et al., 1995)
- Common mechanism = rapid deceleration (I.e. planting/cutting maneuvers or landing from a jump)
- Females at higher risk than males (4-6x higher in soccer) (Mihata et al., 2006)

Risk Factors

- INTRINSIC:
  - Hormonal
  - Anatomical
  - Biomechanical
  - Neuromuscular



- EXTRINSIC:
  - Bracing
  - Physical/visual perturbations
  - Shoe-surface interactions

(Hewett et al., 2006)

Neuromuscular Mechanisms

- Unbalanced medial to lateral quadriceps ratio (Myer et al., 2005, Rozzi et al., 1999)
- Pre-planned vs. unanticipated movements
  - Increased varus-valgus and internal-external rotation moments (Besier et al., 2001)
- Quadriceps-hamstrings antagonist-agonist relationship
  - Deficits in strength and activation of hamstrings (Solomonow et al., 1987)
  - Decreased co-activation (F > M) (Hewett et al., 2006)

(Petrus C, 2006)

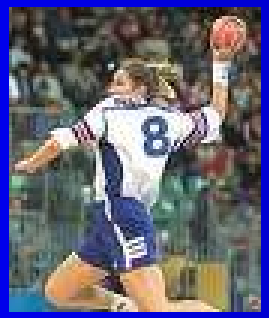
The Need For Prevention

- ~95,000 new ACL injuries/year
- If surgery is required – 6 to 24 months of rehab = $17,000/injury (Beynnon et al., 2005, Hewett et al., 1999)

- ACL reconstruction does not ensure a return to previous activity levels (Fithian et al., 2002)
- If left untreated → chronic knee instability, secondary joint damage and early OA (Andriacchi et al., 2006)

Purpose of Our Review

- Identify the effectiveness of neuromuscular training programs in the prevention of ACL injury in athletes participating in high risk sports



METHOD

Literature Search

- English language
- 1996 – August 2006
- MEDLINE, CINAHL, EMBASE, Web of Science, PubMed, SPORT Discus, CENTRAL and PEDro

Common Search Strategy

1.	Anterior cruciate ligament injur$ or ACL injur$ OR knee injur$
2.	Prevention
3.	1 AND 2
4.	Neuromuscular OR exercise OR training OR balance OR proprioception OR agility OR plyometric$
5.	3 AND 4

The Search continues…

- Grey literature search (ProQuest Dissertations & Theses database)
- Hand search (J. of Orthopedic and Sports Physical Therapy)
- Reference list search of included articles
- Contacted experts

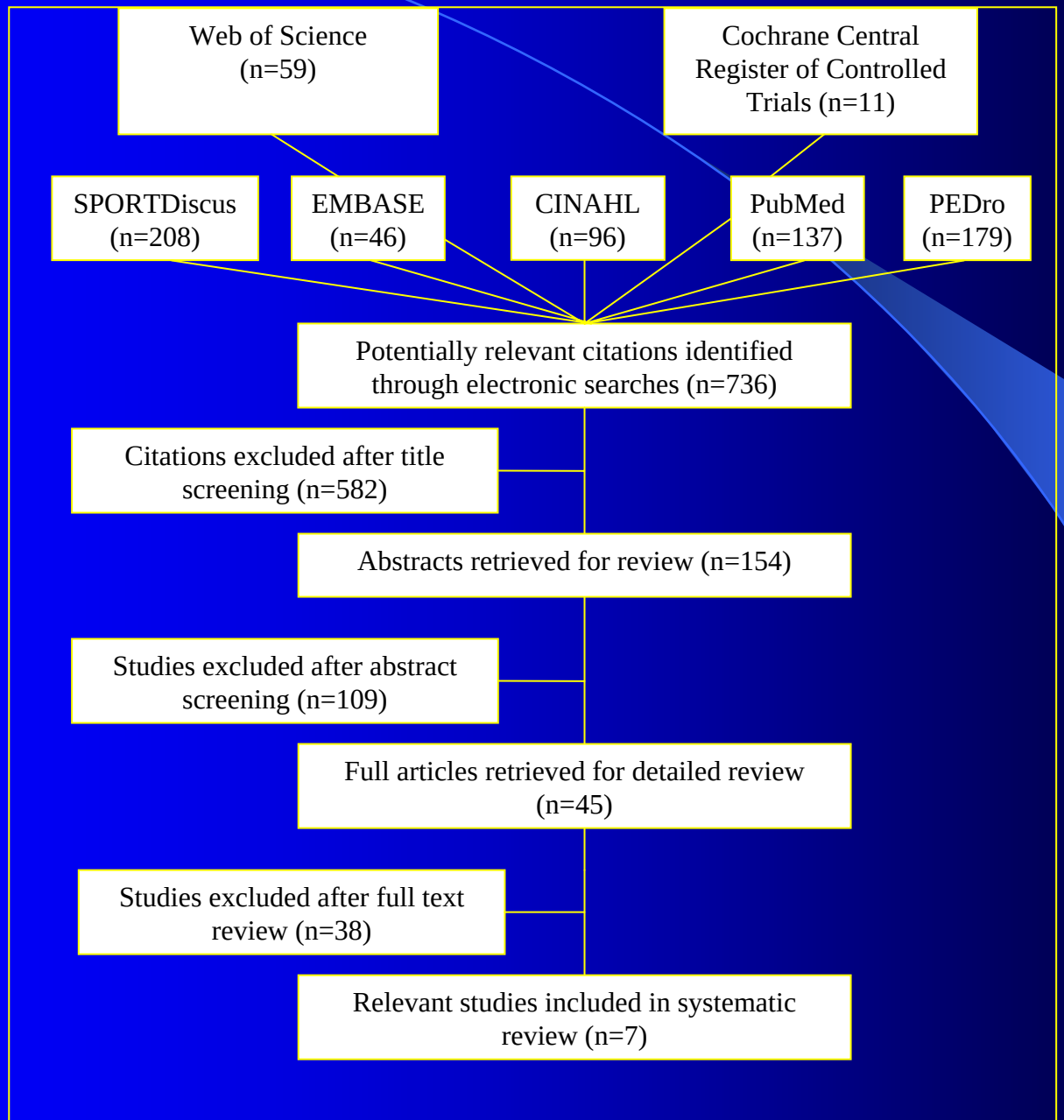
Study Selection Criteria

1) Subjects were male or female athletes participating in one or more of the identified high risk sports
2) The intervention was a neuromuscular training program aimed at preventing knee injury
3) An experimental design was used
4) Outcome measure was ACL injury incidence

Exclusion Criteria

Rehabilitation intervention post-ACL injury

Search Flow Diagram



Review Criteria

- Sackett's levels of evidence as updated by Phillips et al. in the Oxford Centre for Evidence-based Medicine Levels of Evidence (Sackett, 1986, Phillips et al., 2001)

Methodological Quality Criteria

- Megens and Harris as modified by Medlicott and Harris (Megens et al., 1998, Medlicott et al, 2006)
- 10 criteria
- Strong (8-10); moderate (6 or 7); weak (5 or less)

RESULTS

Levels of Evidence

- 5 non-randomized cohort studies
- 2 randomized cohort studies
- All studies used prospective data collection methods
- All identified as level IIb

Methodological Rigor

- Range 3 to 7 (out of 10)
- Mean score = 6
- Median score = 7
- 5 studies scored as “moderate” and 2 as “weak”

Methodological Rigor

Authors	Mandelbaum et al (2005)	Hewett et al. (1999)	Myklebust et al. (2003)	Soderman et al. (2000)	Petersen et al. (2005)	Caraffa et al. (1996)	Heidt et al. (2000)
Randomization	N	N	N	Y	N	N	Y
Inclusion/ Exclusion criteria	Y	Y	Y	Y	Y	Y	Y
Similarity of groups at baseline	Y	N	Y	Y	Y	Y	N
Replicability	Y	Y	N	Y	N	N	N
Reliability	Y	Y	Y	N	Y	Y	N
Validity	Y	Y	Y	N	Y	Y	N
Blinding	N	N	N	N	N	N	N
Dropouts	N	Y	Y	Y	Y	N	N
Long-term results	Y	Y	Y	Y	Y	Y	Y
Adherence	Y	Y	Y	Y	N	N	N
Total score /10	7	7	7	7	6	5	3
Rigor rating	Moderate	Moderate	Moderate	Moderate	Moderate	Weak	Weak

10 Criteria for Methodological Rigor

1) Randomization:

- 2 of the 7 studies randomly assigned subjects to an intervention or control group

2) Subject Inclusion and Exclusion Criteria:

- High school to semi-professional athletes
- Exclusions: Poor compliance; previous knee injury; geography
- 6 studies targeted females; 1 study targeted males

3) Similarity of Groups at Baseline:

- 5 studies reported similarities (I.e. height, weight, age, muscle flexibility, balance/ postural sway of lower extremities, sport experience)

4) Replicability of the Treatment Protocols:

- Must have been stated within the article or have had an accessible reference
- Mandelbaum et al., Hewett et al., and Soderman et al. provided this

5) Outcome Measure Reliability:

- MRI or arthroscopy for diagnosis
- 5 studies met this criteria

6) Outcome Measure Validity:

- Valid if used MRI or arthroscopy for diagnosis
- Therefore, 5 studies also met this criteria

7) Blinding Assessment:

- Must have blinded the subjects, treatment provider AND assessor
- No study met this criteria

8) Reporting of Dropouts:

- Peterson et al., Hewett et al., Mykelbust et al., and Soderman et al provided sufficient detail

9) Long Term Follow-Up:

- All studies were carried out over at least one season (> 6 months)

10) Adherence to Intervention Program:

- Unreported in Caraffa et al. and Heidt et al.

THE STUDIES

Caraffa et al. (1996)

Study Design	Prospective cohort
Rigor & Level of Evidence	5 (“weak”) & IIb
Duration	3 seasons
Target Population	Semi professional and amateur male soccer players
Sample Size	300 Intervention; 300 Control

Caraffa et al. (1996)

Intervention	• Progressive balance board training, stepping exercises, and "neuromuscular techniques" • 20 min/day every day during preseason, 3x/week during active season
Supervision?	Coaches
Compliance	Not reported
Incidence	• 10 Intervention (0.15/team/year) • 70 Control (1.15/team/year)
Program Recommended?	Yes - Significant difference was found between intervention and control groups

Heidt et al. (2000)

Study Design	Randomized Cohort
Rigor & Level of Evidence	3 (“weak”) & IIb
Duration	1 season
Target Population	Female high school soccer players (ages 14-18yrs)
Sample Size	42 Intervention; 258 Control

Heidt et al. (2000)

Intervention	• 7 week preseason program including cardiovascular, plyometrics, strength, and flexibility training (20 sessions) • 2x/week speed training treadmill sessions where grade was elevated • 1x/week plyometric session that progressed throughout 7 weeks from unidirectional to multidirectional to floor obstacles
Supervision?	Not reported
Compliance	Not reported
Incidence	• 1 Intervention (2.4%); 8 Control (3.1%)
Program Recommended?	• Yes - Significant decrease in lower extremity injuries found between intervention and control groups • No significant difference in incidence of ACL injuries – authors attribute this to small sample size

Hewett et al. (1999)

Study Design	Prospective cohort
Rigor & Level of Evidence	7 (“moderate”) & IIb
Duration	1 season
Target Population	Female high school soccer, volleyball, and basketball players
Sample Size	366 Intervention (female); 897 Control (434 males; 463 females)

Hewett et al. (1999)

Intervention	• 6 week preseason jump training program; flexibility, plyometrics, and weight training • 3x/week, 60-90 min/day, total of 18 sessions
Supervision?	Athletic trainer, coaches, physical therapist
Compliance	70% completed 6 week program
Incidence	• 2 Intervention; 6 Control (1 male, 5 female) incidence of *all* knee injuries • 0.43 female control, 0.12 female intervention, 0.09 male control
Program Recommended?	Yes - The untrained group had a *knee* injury rate 3.6 times higher than the female intervention group and 4.8 times higher than the male control group.

Mandelbaum et al. (2003)

Study Design	Prospective cohort
Rigor & Level of Evidence	7 (“moderate”) & IIb
Duration	2 years
Target Population	Amateur female soccer players (ages 14-18 yrs)
Sample Size	• 2000: 1041 Intervention; 1905 control • 2001: 844 Intervention; 1913 Control

Mandelbaum et al. (2003)

Intervention	20 min warm up prior to practices and games: 3 warm-up techniques, 5 stretches, 3 strengthening ex's, 5 plyometric ex's, 3 soccer specific agility drills
Supervision?	Coaches
Compliance	• 2000: 96.15%; 2001: 100%
Incidence	• 2000: 2 Intervention (0.05/athlete/1000 exposures); 32 Control (0.47/athlete/1000 exposures) • 2001: 4 Intervention (0.13/athlete/1000 exposures); 35 Control (0.51/athlete/1000 exposures)

Mandelbaum et al. (2003)

Program Recommended?	Yes - Significant difference was found between intervention and control groups with 88% reduction/athlete in 2000 season and 74% reduction/athlete in 2001 season

Myklebust et al. (2003)

Study Design	Prospective cohort
Rigor & Level of Evidence	7 (“moderate”) & IIb
Duration	3 seasons (1 control; 2 intervention seasons)
Target Population	Female handball players
Sample Size	• 1998/99: Control Season 942 • 1999/2000: Intervention Season 855 • 2000/01: Intervention Season 850

Myklebust et al. (2003)

Intervention	• 15 min circuit of floor ex's, wobble board ex's, balance mat ex's • 3x/week during 5-7 week training period then 1x/week during season
Supervision?	Coaches in first season, physiotherapists in second season
Compliance	• 1999/2000: 26% of teams fulfilled compliance criteria (42% elite division) • 2000/01: 29% of teams fulfilled compliance criteria (50% elite division)

Myklebust et al. (2003)

Incidence	• Control season: 29 (0.14/1000 player-hours) entire cohort, 13 elite division • First Intervention season: 23 (0.13/1000 player-hours) entire cohort,6 elite division • Second intervention season: 17 (0.09/1000 player -hours) entire cohort, 5 elite division
Program Recommended?	Yes - Although no significant difference was found between intervention and control seasons across the entire cohort, there was a significant difference between those who completed the program and those who didn't in the elite division

Petersen et al. (2005)

Study Design	Prospective cohort
Rigor & Level of Evidence	6 (“moderate”) & IIb
Duration	1 season
Target Population	Semi-professional and amateur female handball players
Sample Size	134 Intervention; 142 Control

Petersen et al. (2005)

Intervention	• Six phase balance board and jump exercise program • 3x/week preseason (8 weeks), 1 x week competitive season 10 min/ session
Supervision?	Coaches
Compliance	Not reported
Incidence	1 Intervention (0.04/1000 hours exposure*); 5 Control (0.21/1000 hour exposure)
Program Recommended?	Yes - Although no significant difference was found between intervention and control groups

Soderman et al. (2000)

Study Design	Randomized cohort
Rigor & Level of Evidence	7 (“moderate”) & IIb
Duration	1 season
Target Population	Female soccer players (2nd and 3rd Swedish Divisions)
Sample Size	62 Intervention; 78 Control

Soderman et al. (2000)

Intervention	• Balance board exercises each day for 30 days, then 3x/week for remainder of season • 10-15 min/ session
Supervision?	Self – home program
Compliance	70%
Incidence	4 Intervention; 1 Control
Program Recommended?	• No - Significantly higher incidence rate of major injuries found in intervention group • No significant difference in minor and moderate injuries was found between intervention and control groups

DISCUSSION & IMPLICATIONS

Methodological Rigor & Levels of Evidence

- Rigor and levels of evidence were moderate
- Major contributors to low quality:
  - Randomization
  - Blinding
- Nature of study designs makes these difficult

Intervention Characteristics

- Phase of implementation:
  - Pre-season
  - Competitive season
- Type of intervention:
  - Balance/proprioception
  - Strength
  - Agility
  - Flexibility
  - Plyometrics
  - Combination
- Other training parameters (i.e. frequency, duration, progression, etc.)

Significance

- All studies except 1 found a decrease in incidence of ACL injury
  - Soderman et al. showed a *trend* towards an increase in ACL injury in the intervention group
- Caraffa et al., Hewett et al., and Mandelbaum et al. found *statistically significant* differences
- Myklebust et al. found a significant difference between intervention and control groups *only* in the elite handball division

Implications for Clinical Practice

1) There is moderate evidence to support the use balance/proprioceptive training in ACL injury prevention.

Implications for Clinical Practice

2) There is moderate evidence to support the use of plyometric training in combination with other training components injury prevention of ACL injury.

Implications for Clinical Practice

3) There is promising evidence that balance/proprioception training, strength training and plyometric training when incorporated into a comprehensive training protocol may be effective in reducing the incidence of ACL injury.

- Details insufficient

Implications for Clinical Practice

4) There is moderate evidence that training implemented in the preseason and/or competitive season is effective for ACL injury prevention.

Challenges in Drawing Conclusions

- Quality of studies
- Lack of program details
- Compliance
- Heterogeneity:
  - Intervention parameters
  - Subjects
  - Duration

Implications for Future Research

- Isolation of program components
- More rigorous studies
- Careful documentation to allow replicability of training programs
- Monitoring and reporting compliance
- Intervention parameters need to be established
- Effect of interventions on age and gender

Limitations of Our Review

- Only used publications in English
- Lack of correspondence from experts
- Only used articles accessible free of charge to UBC students

QUESTION PERIOD

Thank you for your attention!

REFERENCES

Andriacchi TP, Briant PL, Bevill SL, Koo S. Rotational changes at the knee after ACL injury cause cartilage thinning. Clinical Orthopaedics & Related Research 2006;442:39-44.

Arendt E, Dick R. Knee Injury Patterns among Men and Women in Collegiate Basketball and Soccer. NCAA Data and Review of Literature. Am J Sports Med 1995;23:694-701.

Besier TF, Lloyd DG, Ackland TR, Cochrane JL. Anticipatory effects on knee joint loading during running and cutting maneuvers. Med Sci Sports Exerc 2001;33:1176-1181.

Caraffa A, Cerulli G, Projetti M, Aisa G, Rizzo A. Prevention of anterior crucuate ligament injuries in soccer; A prospective controlled study of proprioceptive training. Knee Surg, Sports Traumatol, Arthrosc 1996;4:19-21.

Fithian DC, Paxton LW, Goltz DH. Fate of the anterior cruciate ligament-injured knee. Orthopedic Clinics of North America 2002;33.

Heidt RS, Sweeterman LM, Carlonas RL, Traub JA, Tekulve FX. Avoidance of Soccer Injuries with Preseason Conditioning. American Orthopaedic Society for Sports Medicine 2000;28:659-662.

Hewett T, Myer G, Ford F. Anterior cruciate ligament injuries in female athletes. Part 1, Mechanisms and Risk Factors. Am J Sports Med 2006;34:299-311.

Hewett TE, Lindenfeld TN, Riccobene JV, Noyes FR. The effect of neuromuscular traiing on the incidence of knee injury in female athletes. A prospective study. Am J Sports Med 1999;27:699-706.

Mandelbaum BR, Silvers HJ, Watanabe DS, Knarr JF, Thomas SD, Griffin, LY, Kirkendall DT, Garrett W. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. Am J Sports Med 2005;33:1003-1010.

Medlicott MS, Harris SR. A systematic review of the effectiveness of exercise, manual therapy, electrotherapy, relaxation training, and biofeedback in the management of temporomandibular disorder. Phys Ther 2006;86:955-975.

Megens A, Harris SR. Physical therapy management of lymphedema following treatment for breast cancer: a critical review of its effectiveness. Phys Ther 1998;78:1302-1311.

Mihata L, Beutler A, Boden B. Comparing the incidence of anterior cruciate ligament injury in collegiate lacrosse, soccer and basketball players. Implications for anterior cruciate ligament mechanism and prevention. Am J Sports Med 2006;34:899-904.

Myer GD, Ford KR, Hewett TE. The effects of gender on quadriceps muscle activation strategies during a maneuver that mimics a high risk ACL injury position. J Electromyogr Kinesiol 2005;15:181-189.

Myklebust G, Engebretsen L, Braekken IH, Skjolberg A, Olsen OE, Bahl R. Prevention of Anterior Cruciate Ligament Injuries in Female Team Handball players: A Prospective Intervention Study Over Three Seasons. Clinical Journal of Sports Med 2003: 13;71-78.

Petersen W, Braun C, Wiebke B, Schmidt K, Weimann A, Drescher W, Eiling E, Stange R, Fuchs T, Hedderich J, Zantop T. A controlled prospective case control study of a prevention training program in female team handball players: the German experience. Arch Orthop Trauma Surg 2005;125:614-621.

Phillips B, Ball C, Sackett D, Badenoch D, Straus S, Haynes B, Dawes M. 2001. Levels of Evidence and grades of recommendation. Centre for Evidence Based Medicine. 2006 June-August [cited 2006 September 12]. Available from: URL: http://www.cebm.net/levels_of_evidence.asp

Rozzi SL, Lephart SM, Gear WS, Fu FH. Knee joint laxity and neuromuscular characteristics of male and female soccer and basketball players. Am J Sports Med 1999;27:312-319.

Sackett DL. Rules of evidence and clinical recommendations on use of antithrombotic agents. Chest 1986;89:2S-3S.

Soderman K, Werner S, Pietila T, Engstrom B, Alfredson H. Balance board training: prevention of traumatic injuries of the lower extremities in female soccer players? A prospective randomized intervention study. Knee Surg, Sports Traumatol, Arthrosc 2000;8:356-363.

Solomonow M, Baratta R, Zhou BH, Shoji H, Bose W, Beck C, D'Ambrosia R. The synergistic action of the anterior cruciate ligament and thigh muscles in maintaining joint stability. Am J Sports Med 1987;15:207-213.