Training to Stay in the Game: A Systematic Review and Meta-Analysis of ACL Injury Prevention Programs

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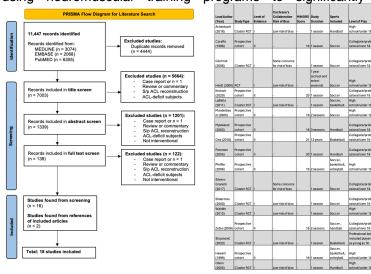
INTRODUCTION:

Both the medical community and the general public have acknowledged the cost, prevalence, and gravity of anterior cruciate ligament (ACL) ruptures. Approximately 400,000 ACL reconstructions are performed each year in the United States alone. Effective ACL injury prevention programs may be paramount in reducing this significant injury burden.

OBJECTIVE: To determine the effectiveness of ACL injury prevention programs and generate updated guidelines that can be implemented to protect athletes from these injuries.

METHODS: Embase, PubMed, and Ovid (MEDLINE) were searched in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Included studies were interventional in nature, focused on ACL injury prevention as opposed to treatment, and provided data on ACL injury rates following intervention implementation. Using random-effects models, the pooled risk ratio (RR) was generated for all data. Sub-analyses were also completed for female-only, high school vs. collegiate/professional, handball, soccer, and balance board data.

RESULTS: A total of 18 articles were identified after review (9 randomized control trials, 9 prospective cohort studies). The 25,166 studied athletes played handball, soccer, basketball, or volleyball (mean age = 19.3, SD = 3.6 years; >85% of players were female). All interventions were studied for a minimum of one season (mean = 1.3, SD = 0.59). Athletes who participated in an ACL injury prevention program were significantly less likely to sustain an ACL rupture with a pooled RR of 0.46 (95% CI, 0.36-0.57; $P < 0.01$; $I^2 = 49\%$; $T^2 = 0.2500$). When analyzed by age, there was a significant risk reduction in ACL rupture for collegiate/professional athletes over age 18 (RR = 0.50; 95% CI, 0.38-0.64; $P < 0.01$; $I^2 = 66\%$; $T^2 = 0.3489$) but no significant change for players under age 18 (RR = 0.35; 95% CI, 0.22-0.55; $P = 0.47$; $I^2 = 0\%$; $T^2 = 0.0738$). Of the 12 studies that included data for female players, the pooled RR was 0.57 and not statistically significant (95% CI, 0.43-0.74; $P = 0.13$; $I^2 = 32\%$; $T^2 = 0.1487$). When assessing the efficacy of ACL injury prevention programs by sport, there was no significant RR for athletes playing soccer (RR = 0.30; 95% CI, 0.19-0.46; $P = 0.06$; $I^2 = 47\%$; $T^2 = 0.4734$) or handball (RR = 0.66; 95% CI, 0.46-0.96; $P = 0.38$; $I^2 = 5\%$; $T^2 = 0.0207$). While all studied interventions emphasized neuromuscular training, players who participated in programs including balance boards exhibited a significantly lower risk of sustaining ACL rupture (RR = 0.49; 95% CI, 0.35-0.67; $P < 0.01$; $I^2 = 74\%$; $T^2 = 0.5800$).

DISCUSSION AND CONCLUSION: Athletes who did not partake in an ACL injury prevention program were nearly twice as likely to sustain an ACL rupture compared to those who did, with particular ACL injury risk reduction in collegiate/professional athletes over age 18 and those who used balance boards. This study provides strong support for using neuromuscular training programs to significantly reduce the risk of ACL rupture among athletes.

PRISMA Flow Diagram for Literature Search

Identification

11,447 records identified

Records identified from:
MEDLINE (n = 3074)
EMBASE (n = 2068)
PubMED (n = 6305)

→ Excluded studies:
Duplicate records removed (n = 4444)

Screening

Records included in title screen (n = 7003)

→ Excluded studies (n = 5664):
- Case report or n = 1
- Review or commentary
- S/p ACL reconstruction
- ACL-deficit subjects

Records included in abstract screen (n = 1339)

→ Excluded studies (n = 1201):
- Case report or n = 1
- Review or commentary
- S/p ACL reconstruction
- ACL-deficit subjects
- Not interventional

Records included in full text screen (n = 138)

→ Excluded studies (n = 122):
- Case report or n = 1
- Review or commentary
- S/p ACL reconstruction
- ACL-deficit subjects
- Not interventional

Included

Studies found from screening (n = 16)

Studies found from references of included articles (n = 2)

Total: 18 studies included

Study Characteristics

Lead Author (Year)	Study Type	Level of Evidence	Cochrane's Collaboration Risk of Bias	MINORS Score	Study Duration	Sports Included	Level of Play	Sex of Players	Salient Components of Intervention
Achenbach (2018)	Cluster RCT	I	Low risk of bias	-	1 season	Handball	High school/under 18	M/F	NMT
Caraffa (1996)	Prospective cohort	II	-	18	1 season	Soccer	Collegiate/professional/over 18	NR	NMT + balance board
Gilchrist (2008)	Cluster RCT	I	Some concerns for risk of bias	-	1 season	Soccer	Collegiate/professional/over 18	F	NMT
Heidt (2000)	RCT	I	Low risk of bias	-	1 year (school and select seasons)	Soccer	High school/under 18	F	NMT
Krutsch (2020)	Prospective cohort	II	-	20	1 season	Soccer	Collegiate/professional/over 18	M	NMT
LaBella (2011)	Cluster RCT	I	Low risk of bias	-	1 season	Soccer, basketball	High school/under 18	F	NMT
Mandelbaum (2005)	Prospective cohort	II	-	19	2 seasons	Soccer	High school/under 18	F	NMT
Myklebust (2003)	Prospective cohort	II	-	18	3 seasons	Handball	Collegiate/professional/over 18	F	NMT + balance board
Omi (2018)	Prospective cohort	II	-	21	12 years	Basketball	Collegiate/professional/over 18	F	NMT
Petersen (2005)	Prospective cohort	II	-	20	1 season	Handball	Collegiate/professional/over 18	F	NMT + balance board
Pfeiffer (2006)	Prospective cohort	II	-	19	2 seasons	Soccer, basketball, volleyball	High school/under 18	F	NMT
Silvers-Granelli (2017)	Cluster RCT	I	Some concerns for risk of bias	-	1 season	Soccer	Collegiate/professional/over 18	M	NMT + balance board
Söderman (2000)	Cluster RCT	I	Low risk of bias	-	1 season	Soccer	Collegiate/professional/over 18	F	NMT + balance board
Waldén (2012)	Cluster RCT	I	Low risk of bias	-	1 season	Soccer	High school/under 18	F	NMT
Zebis (2008)	Prospective cohort	II	-	18	2 seasons	Soccer, handball	Collegiate/professional/over 18	F	NMT + balance board
Stojanović (2023)	Cluster RCT	I	Low risk of bias	-	1 season	Basketball	Professional but included players as young as 16	M/F	NMT
Hewett (1999)	Prospective cohort	II	-	19	1 season	Soccer, basketball, volleyball	High school/under 18	F (M included in controls)	NMT + balance board
Olsen (2005)	Cluster RCT	I	Low risk of bias	-	1 season	Handball	High school/under 18	M/F	NMT

Forest Plot

Study	Experimental Events	Total	Control Events	Total	Weight	Risk Ratio IV, Fixed, 95% CI
Achenbach, et al.	1	168	2	111	0.9%	0.33 [0.03; 3.60]
Caraffa, et al.	10	300	70	300	12.0%	0.14 [0.08; 0.27]
Gilchrist, et al.	6	583	10	852	4.9%	0.88 [0.32; 2.40]
Heidt, et al.	1	42	8	258	1.2%	0.77 [0.10; 5.98]
Krutsch, et al.	15	583	28	601	13.1%	0.61 [0.33; 1.13]
LaBella, et al.	2	737	6	755	1.9%	0.34 [0.07; 1.69]
Mandelbaum, et al.	6	1885	67	3818	7.2%	0.18 [0.08; 0.42]
Myklebust, et al. first season	23	855	29	942	17.1%	0.87 [0.51; 1.50]
Myklebust, et al. second season	17	850	29	942	14.2%	0.65 [0.36; 1.17]
Omi, et al.	9	448	16	309	7.7%	0.39 [0.17; 0.87]
Petersen, et al.	1	134	5	142	1.1%	0.21 [0.03; 1.79]
Pfeiffer, et al.	3	577	3	862	1.9%	1.49 [0.30; 7.38]
Silvers-Granelli, et al.	3	675	16	850	3.3%	0.24 [0.07; 0.81]
Söderman, et al.	4	121	1	100	1.1%	3.31 [0.38; 29.11]
Waldén, et al.	7	2479	14	2085	6.1%	0.42 [0.17; 1.04]
Zebis, et al.	0	20	2	20	0.6%	0.20 [0.01; 3.91]
Stojanov..., et al.	1	57	3	55	1.0%	0.32 [0.03; 3.00]
Hewett, et al.	2	366	5	463	1.9%	0.51 [0.10; 2.59]
Odd-Egil Olsen, et al.	3	958	10	879	3.0%	0.28 [0.08; 1.00]
Total (95% CI)		11784		14344	100.0%	0.46 [0.36; 0.57]

Heterogeneity: Tau^2 = 0.2500; Chi^2 = 35.17, df = 18 (P < 0.01); I^2 = 49%