Frank R. Noyes
Sue Barber-Westin
Editors

ACL Injuries in the Female Athlete

Causes, Impacts, and Conditioning Programs

With DVD-ROM

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Preface

The dilemma of the gender disparity in anterior cruciate ligament (ACL) injuries began nearly 20 years ago when unsettling data began to appear in the *American Journal of Sports Medicine* from the editors' orthopedic and sports medicine center and the National Collegiate Athletic Association:

> The injury rate of serious knee ligament injuries among female athletes was 5.75 times that of male athletes, a difference that proved to be statistically significant (1994) [6].
> Specifically, female soccer players had an ACL injury rate at least twice as high as male players in any given year. Female basketball players had an ACL injury rate at least three times that of male players in 4 of the 5 years sampled (1995) [1].

Although no scientific data existed to determine why female athletes in certain sports were suffering higher rates of ACL injuries than their male counterparts, there were enough theories of causative risk factors to support the initiation of special training programs designed to decrease this problem;

> One starts an action simply because one must do something.
>
> – T.S. Eliot

Although it may have seemed premature to promote training of female athletes involved in soccer, basketball, and other high-risk activities, a few pioneers set forth to improve or change aspects of these athletes' movement patterns that seemed to inherently predispose them for ACL injury:

> This training may have a significant effect on knee stabilization and prevention of serious knee injury among female athletes (1996) [3].

> This prospective study demonstrated a decreased incidence of knee injury in female athletes after a specific plyometric training program (1999) [4].

Following the publication in 1999 of a neuromuscular training program that reduced the incidence of ACL injuries in female high school athletes, this topic generated tremendous interest almost instantly. Researchers from around the world were soon involved in studying risk factors hypothesized to cause the gender disparity and developing other training programs designed to reduce the incidence of noncontact ACL injuries. At the time of writing, over 300 original research investigations had been published that focused on ACL injuries in the female athlete.

Having been at the forefront of this research topic, the editors find it refreshing to see the amount of intellectual energy and dollars that have been devoted to this area. There is little doubt that the findings first described in 1994–1995 did not represent a trend or fad but a truly important problem worthy of bringing the interest of the best minds involved in sports medicine to try to solve or reduce this problem. In fact, multiple "ACL research retreats" (occurring in 1999, 2001, 2003, 2005, 2006, 2008, 2010, 2012) and consensus statements from organizations such as the International Olympic Committee [7] demonstrate the attention and emphasis the female athlete ACL injury dilemma has received internationally.

As shown in this textbook, many more investigators are studying the causative factors producing the higher incidence of ACL injuries in female athletes than are involved in prevention training. Debate exists regarding the continuing problem of deciphering the true risk factors, and in fact, there remain questions on the exact mechanisms of this injury. Public health experts stress the critical need to understand the etiology of why athletic injuries occur because

> Prevention cannot be instigated until this information is available because the specific focus and targeting of prevention programs is unclear [2].

So, at least for ACL injuries, a paradox exists in that we are still in the process of understanding the mechanisms and risk factors for the injury, yet prevention programs have reduced the incidence in some female athletic populations. This is true both for a few individual training programs and for meta-analyzed data:

> The findings from this review lend support to ACL injury prevention programs designed to prevent unopposed excessive quadriceps force and frontal-plane or transverse plane (or both) moments to the knee and to encourage increased knee flexion angle during sudden deceleration and acceleration tasks (2008) [9].

> Our study indicated strong evidence in support of a significant effect of ACL injury prevention programs. Our pooled estimates suggest a substantial beneficial effect of ACL injury prevention programs, with a risk reduction of 52% in the female athletes and 85% in the male athletes (2012) [8].

If it seems we are getting ahead of ourselves, that may be true. However, the ever-growing interest in ACL injury prevention training is indicative that many health professionals, athletes, coaches, and parents believe that some type of preventative effort is better than nothing. In fact, the editors' nonprofit research foundation has certified over 1,360 individuals to conduct neuromuscular ACL injury prevention programs in their communities and medical practices. A recent Bing search of "ACL Injury Prevention Training" revealed 515,000 hits, highlighting the popularity of this topic.

Unfortunately, not everyone has jumped on the bandwagon regarding ACL injury prevention training. Many authors have noted problems convincing coaches to agree to add this type of training to their practice schedules or to train their athletes before the season begins. In a recent study [5], 258 high school coaches in the Chicago area were invited to participate in a coach-led ACL injury prevention training program. Only 95 (37 %) enrolled. There

remains a tremendous need and responsibility of medical health professionals to educate those involved with female athletes of the devastating consequences of ACL injuries and the need to prevent them.

One potential solution to the "coach-not-interested" problem is to provide training programs that both enhance athletic performance and reduce the incidence of ACL injuries. This textbook describes programs designed for high-risk sports such as soccer and basketball that have accomplished both of these goals.

Another solution is to study and identify simple field tests to detect athletes with neuromuscular problems and imbalances that require correction. While laboratory work must continue using the most advanced three-dimensional motion, force plate, electromyographic, and other equipment available, realistic and cost-effective tests are required. These could be incorporated into preseason physicals done by physicians or conducted by coaches as part of their athlete testing regimen. Several such field tests are detailed in this book.

This textbook was designed to compile the many different approaches taken by clinicians and scientists regarding the female ACL injury problem. Our goal is to highlight the findings and current viewpoints of some of the individuals actively involved in this area of research. We are grateful to the guest authors, many of whom have published extensively on this topic, for their contributions to this effort.

It is our hope that someday, ACL injury prevention training will truly be widespread and perhaps even a part of routine physical education classes at schools. We agree with a recent consensus statement that we need to consider

> …increasing our focus on the youth athlete and taking more of a public health approach in our injury-risk screening and injury-prevention strategies in this population [10].

Only through widespread use of prevention training will the female ACL injury problem be solved or at least significantly reduced. Until then, it remains the responsibility of those clinicians and scientists involved to continue their efforts to educate the general public and conduct research in the areas of risk factors, risk screening, and prevention programs.

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Acronyms

ACL	Anterior cruciate ligament
AE	Athlete-exposure
AM	Anteromedial
AMI	Arthrogenic muscle inhibition
ANOVA	Analysis of variance
AP	Anteroposterior
BMD	Bone mineral density
BMI	Body mass index
B-PT-B	Bone-patellar tendon-bone
BSSTM	Behavioral and social science theories and models
CD	Compact disc
CNS	Central nervous system
cm	Centimeters
COF	Coefficient of friction
COM	Center of mass
COP	Center of pressure
COMP	Cartilage oligomeric matrix protein
DEXA	Dual energy x-ray absorptiometry
DPSI	Dynamic postural stability index
EMG	Electromyographic or electromyography
ER	External rotation
FAST-FP	Functional Agility Short-Term Fatigue Protocol
FIFA	Federation Internationale de Football Association
FPPA	Frontal plane projection angle
GAG	Glycosaminoglycans
GMAX	Gluteus maximus
GMED	Gluteus medius
GRF	Ground reaction force
GRFV	Ground reaction force vector
rGRFV	Resultant ground reaction force vector
GTO	Golgi-tendon organs
HBM	Health Belief Model
IC	Initial contact
ICC	Intraclass correlation coefficients
IEMG	Integrated electromyography
IKDC	International Knee Documentations Committee
IR	Internal rotation
IR/ER	Internal rotation / external rotation

H:Q	Hamstrings-to-quadriceps
JPS	Joint position sense
KIPP	Knee Injury Prevention Program
kg	Kilograms
KLIP	Knee Ligament Injury Prevention
KT and KT-2000	Knee arthrometer
LESS	Landing Error Scoring System
M	Meters
min	Minutes
MMPs	Metalloproteinases
mo	Month
MRI	Magnetic resonance imaging
MSFT	Multi-stage fitness test
ms	Milliseconds
MVC	Maximal voluntary contraction
MVE	Maximal voluntary excursions
NCAA	National Collegiate Athletic Association
NFL	National Football League
N	Newtons
Nm	Newton meters
OA	Osteoarthritis
PA	Posteroanterior
pEKAbM	Peak external knee abduction moment
PEP	Prevent Injury and Enhance Performance
PL	Posterolateral
PCL	Posterior cruciate ligament
pTIRM	Peak tibial internal rotation moment
QH	Quadriceps-hamstrings
RM	Repetition max
s	Seconds
SEBT	Star Excursion Balance Test
SEPs	Somatosensory evoked potentials
SLO-FP	Slow Linear Oxidative Fatigue Protocol
SPECT	Single-photon emission computed tomography
STG	Semitendinosus-gracilis
TIMP	Tissue inhibitors of metalloproteinases
TDPM and TTDPM	Threshold for detection of passive motion
TRIPP	Translating Research into Injury Prevention Practice
TTDPM	Threshold to detect passive motion
U.S.	United States
vGRF	Vertical ground reaction force
VMO	Vastus medialis oblique
VO_2max	Maximal oxygen uptake
WIPP	Warm-up for Injury Prevention and Performance
wk	Week
×	Times
yr	Year
3-D	3 dimensional
2-D	2 dimensional