ACL INJURY / RE-INJURY PREVENTION

IDENTIFYING RISK FACTORS AND PROGRAMMING FOR INJURY PREVENTION

MATT JORDAN, M.Sc., CSCS

PhD Candidate, Faculty of Medical Science, University of Calgary

Director of Strength and Conditioning, Canadian Sport Institute-Calgary

Director of Sport Science | Sport Medicine, Canadian Alpine Ski Team

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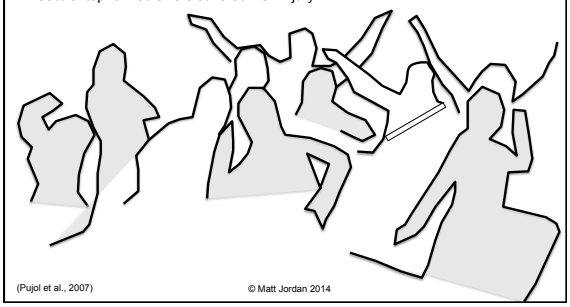
PRESENTATION OVERVIEW

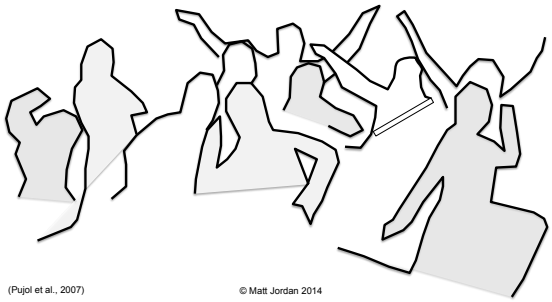
- Identify modifiable (trainable) risk factors for ACL injury
- Consequences of ACL injury
- Programming for ACL injury / re-injury prevention

- A database of ski racers with French Alpine Ski Team was analyzed
- Of 379 athletes registered, 28% suffered at least one ACL injury
- 50% of top ranked skiers suffered ACL injury

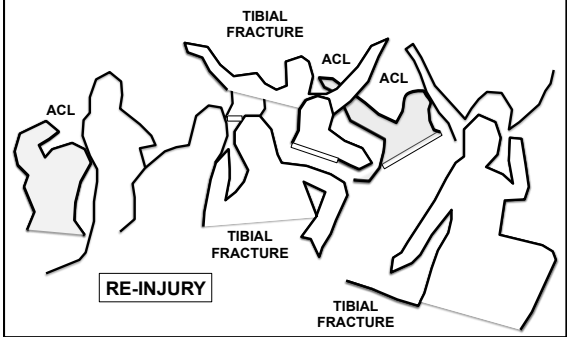


(Pujol et al., 2007)

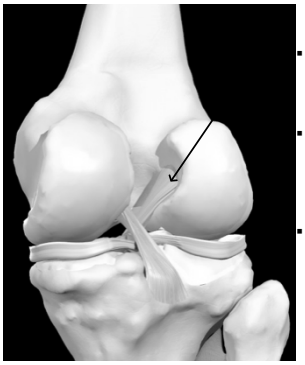
- More than 30% of top ranked skiers suffered ACL re-injury



(Pujol et al., 2007)



NON-CONTACT ACL INJURY



- Female athletes at greater risk (4-6x male counterpart) (Arendt et al., 1995; Myer et al., 2009; Prodromos et al., 2008)
- Non-contact injury occurs in transitional zones (i.e. deceleration of the BCM) (Beynnon et al., 1998)
- Increased risk for non-contact ACL injury attributable to risky biomechanics and altered intermuscular coordination (Hewett et al., 2005; Zebis et al., 2009)

FORCES THAT LOAD THE ACL

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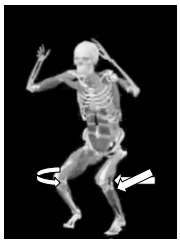
Prodromos, (2008). The Anterior Cruciate Ligament: Reconstruction and Basic Science

FORCES THAT LOAD THE ACL



Anterior shear load on the tibia ***

Valgus loading

Tibial internal rotation

0-30° and 90° + knee flexion

Aggressive quadriceps contraction / hamstring inactivation

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ACL RISK FACTORS: LANDING MECHANICS

- Rapid eccentric deceleration (landing jumps / changing direction) high risk sport movement
- Hard landing (Hewett et al., 2005)
- Greater posterior vGRF
- Small angles of knee flexion / quad strength dominant (Demorat et al., 2004 ; Colby et al., 2000; Myer et al., 2006)
- Time frame of injury < 50 ms (Krosshaug et al., 2007)
- Highlights importance of pre-activation strategies and rapid muscular force development

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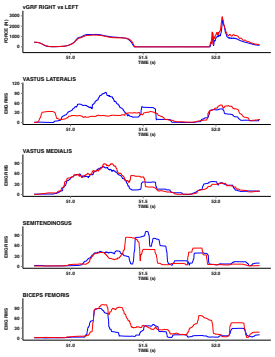
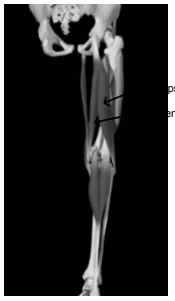
ACL RISK FACTORS: HAMS / QUADS



- Female athletes may have altered H/Q activation and reduced hamstrings strength (Huston & Wojstys, 1996; Prodromos et al., 2008; Zebis et al., 2009; Zebis et al., 2011)
- ACL injured females increased VL-ST activity difference (Zebis et al., 2009)
- ACL injured females had lower hamstrings strength but no difference in quadriceps strength compared to matched male controls (Myer et al., 2009)
- Quadriceps dominant landings linked to increased ACL loading (Bessier et al., 2003; Demorat et al., 2004; Markolf et al., 2004)

HAMSTRINGS – AN ACL AGONIST



ps femoris

endinosus

- Hamstrings important ACL agonist (decreases ACL loading) (Mac Williams et al., 1999; Markolf et al., 2004)
- Assists by preventing anterior translation of tibia b/w 30-90° flexion but not in extension (Mac Williams et al., 1999; Markolf et al., 2004)
- Medial hamstrings / medial quadriceps (VM) important for ACL unloading and medial joint compression (anti-valgus) (Zebis et al., 2009)
- H/Q co-contraction increases valgus/ varus stiffness (Mac Williams et al., 1999)

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MECHANISMS OF INJURY

(Gio Auletta, Pentaphoto)

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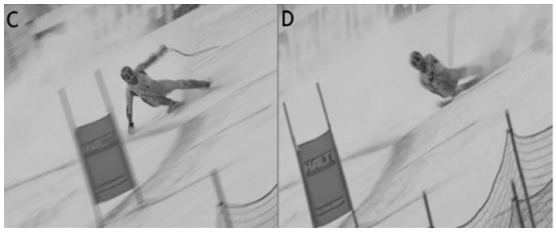
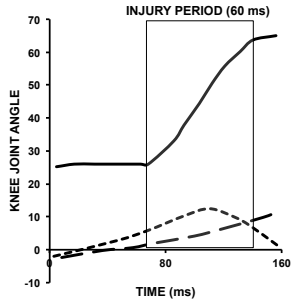
SLIP AND CATCH



(Bere et al., 2011)

SLIP AND CATCH MECHANISM

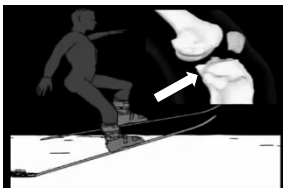


- Knee Flexion
- Valgus
- Internal Rotation

- Rapid increase in knee flexion 26° to 63°

Barone et al. *Skiing Trauma and Safety, 12th Edition* (1999): 63-81.
Bere et al. *The American journal of sports medicine* 41.5 (2013): 1067-1073.

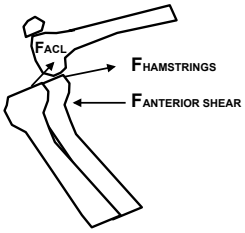
LANDING BACK WEIGHTED



- Skier out of balance and backward in flight
- Lands on ski tails
- Boot and knee extensor torque cause anterior translation of tibia

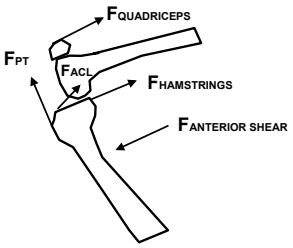
(Bere et al., 2011)

IMPORTANCE OF THE HAMSTRINGS



(Barrata et al., 1988; Herzog & Read, 1993; Mac Williams et al., 1999; Markolf et al., 2004; Prodromos et al., 2008)

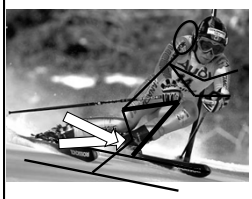
IMPORTANCE OF THE HAMSTRINGS



(Barrata et al., 1988; Herzog & Read, 1993; Mac Williams et al., 1999; Markolf et al., 2004; Prodromos et al., 2008)

IMPORTANCE OF THE HAMSTRINGS

SUMMARY OF MECHANISMS



- Range of knee flexion
- Skier out of balance
- Lateral to medial knee joint loading (valgus loading)
- Twisting load (internal rotation of tibia)
- Back to front load on tibia (anterior displacement of tibia)
- Time frame of injury (< 60 ms)

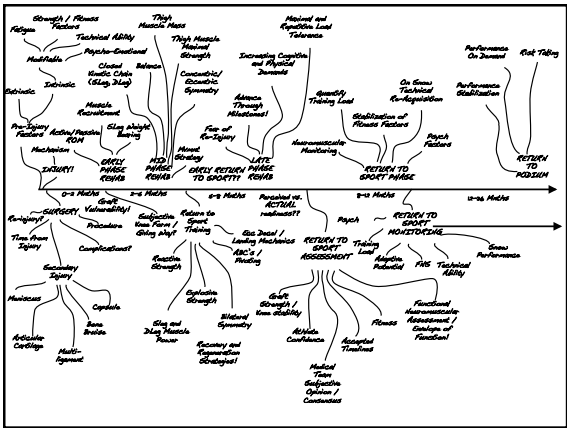
RISKS FACTORS FOR ACL INJURY

- Equipment
- Speed
- Changing snow conditions
- Course setting
- **Physical factors (e.g. fitness, strength)**

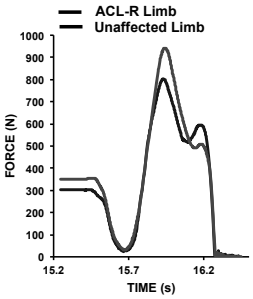
(Spörri et al., 2012)

THE INJURY / RE-INJURY CYCLE

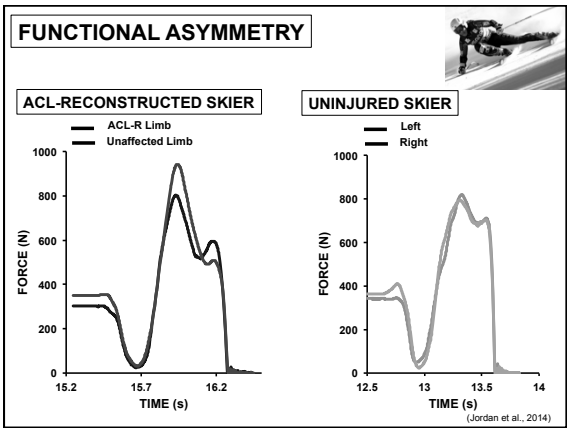
(Bere et al., 2011; Bere et al., 2011; Ferguson, 2009; McConkey, 1996; Natri et al., 1999; Pujol et al., 2007)

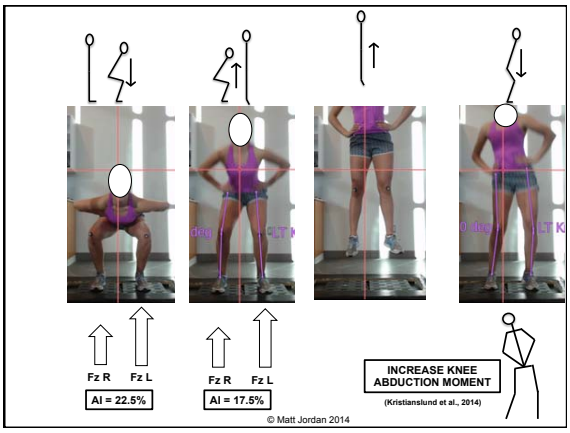


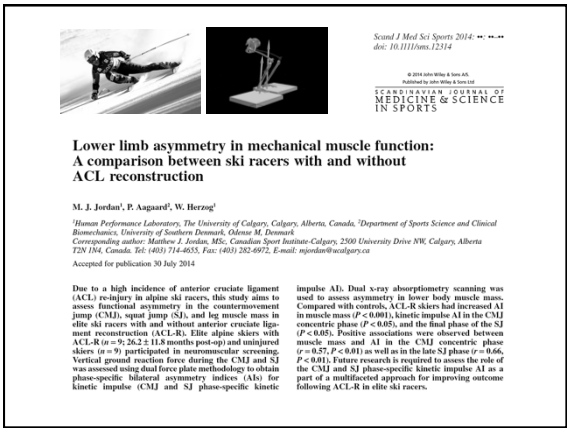
FUNCTIONAL ASYMMETRY



(Jordan et al., 2014)







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Lower limb asymmetry in mechanical muscle function: A comparison between ski racers with and without ACL reconstruction

M. J. Jordan[1], P. Aagaard[2], W. Herzog[1]

[1]Human Performance Laboratory, The University of Calgary, Calgary, Alberta, Canada, [2]Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense M, Denmark
Correspondence author: Matthew J. Jordan, MSc, Canadian Sport Institute-Calgary, 2500 University Drive NW, Calgary, Alberta T2N 1N4, Canada. Tel: (403) 714-6655, Fax: (403) 282-6972, E-mail: mjordan@ucalgary.ca

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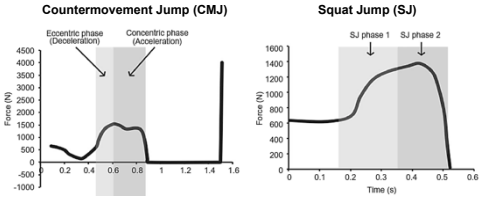
Due to a high incidence of anterior cruciate ligament (ACL) re-injury in alpine ski racers, this study aims to assess functional asymmetry in the countermovement jump (CMJ), squat jump (SJ), and leg muscle mass in elite ski racers with and without anterior cruciate ligament reconstruction (ACL-R). Elite alpine skiers with ACL-R ($n = 9$; 26.2 ± 11.8 months post-op) and uninjured skiers ($n = 9$) participated in neuromuscular screening. Vertical ground reaction force during the CMJ and SJ was assessed using dual force plate methodology to obtain phase-specific bilateral asymmetry indices (AIs) for kinetic impulse (CMJ and SJ phase-specific kinetic impulse AI). Dual x-ray absorptiometry scanning was used to assess asymmetry in lower body muscle mass. Compared with controls, ACL-R skiers had increased AI in muscle mass ($P < 0.001$), kinetic impulse AI in the CMJ concentric phase ($P < 0.05$), and the final phase of the SJ ($P < 0.05$). Positive associations were observed between muscle mass and AI in the CMJ concentric phase ($r = 0.57$, $P < 0.01$) as well as in the late SJ phase ($r = 0.66$, $P < 0.01$). Future research is required to assess the role of the CMJ and SJ phase-specific kinetic impulse AI as a part of a multifaceted approach for improving outcome following ACL-R in elite ski racers.

Table 1. Subject characteristics (mean ± SD)

Status	Sex	*n*	Age (years)	Mass (kg)	Body fat (%)	Months post-op	CMJ peak power (W/kg)	SJ peak power (W/kg)
ACL-R skiers	Female	5	23.8 ± 3.3	70.3 ± 5.7	21.6 ± 2.5	28.4 ± 13.5	40.4 ± 5.4	40.4 ± 6.2
	Male	4	30.5 ± 2.1	86.6 ± 9.9	14.7 ± 3.1	23.5 ± 10.6	49.9 ± 3.9	50.1 ± 3.3
	Female	4	21 ± 1.4	66.8 ± 4.5	15.3 ± 2.5	NA	45.2 ± 3.8	43.5 ± 5.0
Uninjured skiers	Male	5	23.4 ± 2.5	80.7 ± 1.7	13.8 ± 2.2	NA	52.7 ± 4.9	52.3 ± 4.3

ACL-R, anterior cruciate ligament reconstruction; CMJ, countermovement jump; SJ, squat jump.



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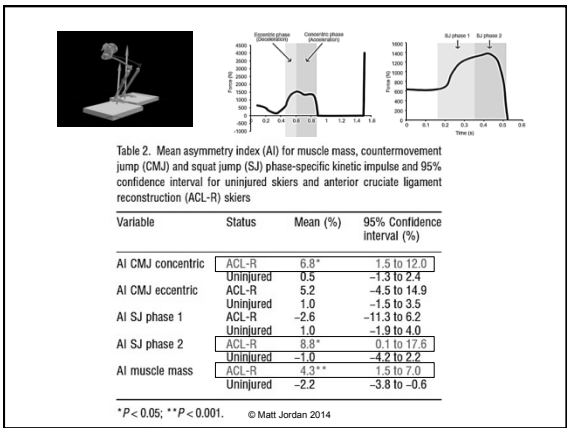
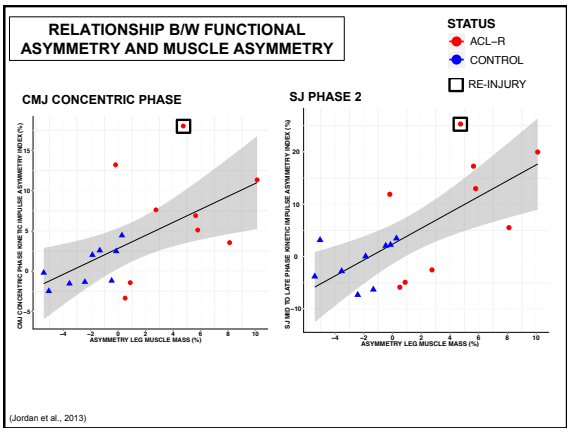


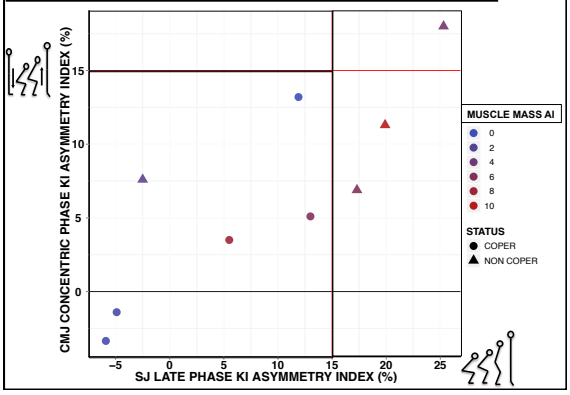
Table 2. Mean asymmetry index (AI) for muscle mass, countermovement jump (CMJ) and squat jump (SJ) phase-specific kinetic impulse and 95% confidence interval for uninjured skiers and anterior cruciate ligament reconstruction (ACL-R) skiers

Variable	Status	Mean (%)	95% Confidence interval (%)
AI CMJ concentric	ACL-R	6.8*	1.5 to 12.0
	Uninjured	0.5	−1.3 to 2.4
AI CMJ eccentric	ACL-R	5.2	−4.5 to 14.9
	Uninjured	1.0	−1.5 to 3.5
AI SJ phase 1	ACL-R	−2.6	−11.3 to 6.2
	Uninjured	1.0	−1.9 to 4.0
AI SJ phase 2	ACL-R	8.8*	0.1 to 17.6
	Uninjured	−1.0	−4.2 to 2.2
AI muscle mass	ACL-R	4.3**	1.5 to 7.0
	Uninjured	−2.2	−3.8 to −0.6

*$P < 0.05$; **$P < 0.001$. © Matt Jordan 2014



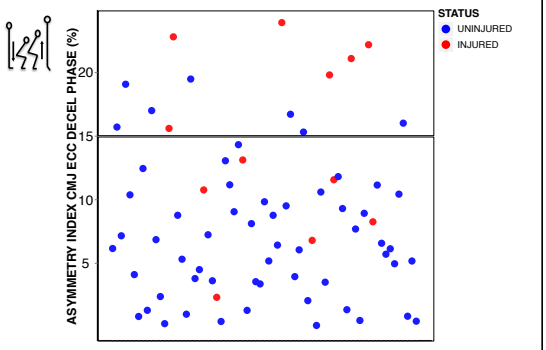
IDENTIFYING AT RISK SKIERS:KINETIC IMPULSE ASYMMETRY INDEX



IDENTIFYING AT RISK ATHLETES

- N = 71 athletes
- Females: n=51, Age=20.6±2.3 years, Body Mass = 67.8±11.5 kg
- Males: n=20, Age=20.1±1.7 years, Body Mass = 78.7±16.5 kg)
- Alpine skiing, luge, soccer, rugby, wrestling
- Assessed at the start of the off-season preparatory period and throughout training (1x/week)

IDENTIFYING PREVIOUSLY UNINJURED AT RISK ATHLETES



Odds of injury 1.2x (95% CI = 1.1-1.4x) (P<0.01)

ACL INJURIES 2010 – 2014 = NONE

ACL RE-INJURIES = NONE

LOWER BODY RE-INJURIES = 2

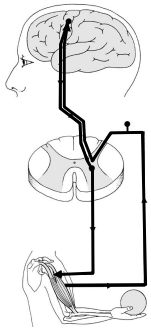
STRATEGIES FOR ACL INJURY/RE-INJURY PREVENTION

TRAINING CONSIDERATIONS

WHERE IS THE BREAKDOWN?

Can the system find the right solution?

Can the motor system generate the right solution?



(Aagaard, 2003; Sale, 2003)

TRAINING FOR INJURY PREVENTION

MOTOR CONTROL	NEUROMUSCULAR FACTORS
Unilateral Deceleration Motor Control	Deceleration Strength
Bilateral Deceleration Motor Control	Positional Strength
Core Control	Bilateral Force Symmetry
Muscle Pre-Activation / Anticipation	Rate of Force Development (Explosive Strength)
Expected / Unexpected Events	Thigh Muscle Strength Curve
Rested and Fatigued	Inter-Muscular Synergy and Muscle Balance

WARM UP

ACTIVATION

MOTOR CONTROL

PRIMARY LIFTS

SECONDARY LIFTS

ASSISTANT CIRCUIT

MOTOR CONTROL

- → Use a variety of loads and velocities but ensure some specificity
- → Identify compensation strategies - 'we are designed to compensate'
- → Groove motor patterns under expected conditions
- → Challenge system with fatigue conditions or unexpected conditions
- → Performed daily as a part of warm up and in combination with activation exercises

WARM UP

Quotidian movement assessment

Dynamic warm up

Mobility

ACTIVATION

1. Omni Prone Plank 
2. Omni Side Plank 
3. Mini Band Mummy Walks 
4. Mini Band Full Squats 

MOTOR CONTROL

1. Jump Rudiment 
2. Double Leg Freeze Drops 
3. Single Leg Drops 
4. Single Leg Drops Eyes Closed 

LOWER BODY STRENGTH

STRENGTH DEVELOPMENT

→ Don't train on top of poor technique

→ Develop range of motion appropriately

→ Use a combination of uni-lateral and bilateral lifts

→ Develop positional strength AND positional rapid force production

NEUROMUSCULAR FACTORS

→ Lower body symmetry

→ Train to be ambidextrous

→ Strengthen ACL agonists

→ Identify periods of strength development and strength maintenance

→ Performed 1-2x / week as a part of microcycle

ESSENTIAL MOVEMENTS

→ Full range of motion unilateral / bilateral exercises

→ Hamstring (closed chain / open chain)

→ Hip abductor strength

→ Quadriceps strength balance (VM vs. VL)

ZONE	TYPE	REPETITION RANGE	RELATIVE INTENSITY 1RM=100%	TRAINING EFFECT
1	SSC	6-10	BW – 20%	REACTIVE STRENGTH
2	DYNAMIC EFFORT	3-8	30% - 80%	EXPLOSIVE STRENGTH / MECHANICAL POWER
3	REPEATED EFFORT	6-15	60% - 85%	MUSCLE HYPERTROPHY / WORK CAPACITY
4	MAXIMAL EFFORT	1-6	85% - 100%	MAXIMAL MUSCLE STRENGTH

PRIMARY LIFTS

STRONG AND EXPLOSIVE BELOW 90 DEGREES

1. Full Power Clean

2. Full Back Squat

SECONDARY LIFTS

BILATERAL STRENGTH SYMMETRY / CORE STRENGTH

3. Full Depth Single Leg Squat Off Box

4. Band Resisted Romanian Dead Lift

ASSISTANT CIRCUIT

HAMSTRING / QUADRICEPS STRENGTH BALANCE

5A. Heel Elevated Step Down

5B. Eccentric Leg Curl

5B. Band Hip Abduction

FATIGUE

- → Ski related injuries occur in a fatigued state (Bere et al., 2013)
- → Fatigue leads to risky biomechanics in landing (Kernozek et al., 2008)
- → Alterations in hamstrings/quadriceps co-contraction observed in an acutely fatigued state (Zebis et al., 2011)
- → Evaluating neuromuscular function in the ACLR athlete under fatigue (Myer et al., 2006)

BALANCE AND LOWER BODY MOTOR CONTROL

- → Does an exercise **require** balance or **train** balance
- → New and unpredictable movements train balance
- → The **best** movement = the **new** movement

SUMMARY

- → ACL injury affects many athletes (ski racers, recreational skiers, female athletes in field sports)
- → We can identify modifiable (trainable) risk factors
- → Programming for injury prevention is multi-faceted
- → Daily motor control component
- → Strengthening component
- → Strategies can be very effective for injury prevention

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