SPORT DEMAND ANALYSIS

FREESTYLE MOGUL SKIING

2018-2019
(Updated: 01/2020)

Joshua B. Bullock
Athletic Development Coach: Freestyle Mogul Skiing
U.S. Ski & Snowboard

Table of Contents

SECTION #1

OVERVIEW OF SPORT

Mogul skiing is a freestyle skiing competition consisting of one timed run of free skiing on a steep, heavily moguled course, stressing technical turns, aerial maneuvers and speed (Federation International de Ski, 2013-2014). Internationally, the sport is contested at the Federation International De Ski (FIS) World Cup Tour, FIS Freestyle World Ski Championships, and at the Winter Olympic Games.

The first competition involving mogul skiing occurred in 1971.
The FIS created the Freestyle World Cup Circuit in 1980. The first World Championships were held in 1986, and are currently held in odd-numbered years. It has been a medal event in the Winter Olympics since 1992.

Dual mogul competition consists of elimination rounds where pairs of competitors compete against each other. Each winner advances to the next round and each loser is eliminated until a final result is achieved. Dual mogul competition is not held in Olympic years.

Duration

The duration of a typical moguls run varies by grade, length of course, and overall course conditions. Below are the pace times for courses on the 2017-2018 World Cup Tour.

VENUE	MEN	WOMEN
RUKA	20.87	24.43
THAIWOO	22.71	26.59
CALGARY	20.87	24.43
DEER VALLEY	24.46	28.63
TREMBLANT	22.33	26.13
PYEONGCHANG (OWG)	24.27	28.40
THAIWOO	22.71	26.59
MEGEVE	25.33	29.65
AVERAGE	**22.94**	**26.86**

Scoring

Single Moguls

Moguls competition scoring consists of three parts (Federation International de Ski, 2013-2014).

1) Aerial acrobatics constitute 20% of the score (0.0 – 20) and are broken down in to two parts: a) form and b) difficulty.

2) Turns, which refers to the technical evaluation of how well a competitor turns through the moguls, constitutes 60% of the score (0.0 – 60). Turn evaluation is scored using rhythmic changes in direction of travel to either side of the fall line, utilizing an aggressive, controlled technique.

3) Speed constitutes 20% of the score (0.0 – 20). Speed is simply the distance (m) divided by the time (s) taken to complete the run. The pace for moguls is 8.8 m/s for women and 10.3 m/s for men.

Scoring Procedures

Seven Judges evaluate the competitor's performance using a split scoring system as follows:

Five Turn Judges independently evaluate the competitor's performance. The high and low scores are discarded and the remaining three scores added together.

Two Air Judges independently evaluate the competitor's aerial maneuvers. The scores are averaged for a total air score and truncated to two decimal places.

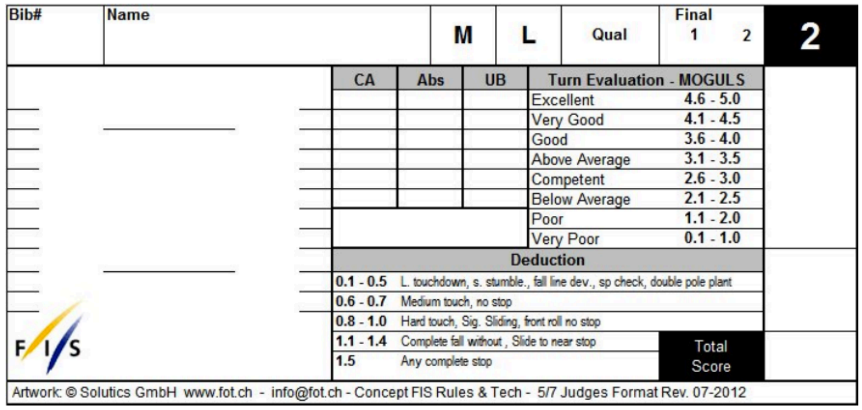
The average of the two air scores is added to the total of the three counting turn scores to get the competitors total judges score. The speed score is added to the total judges score to determine the competitor's complete score.

Dual Moguls

The dual mogul competition consists of elimination rounds where pairs of competitors compete against each other. Each loser is eliminated and each winner advances to the next round until a final result is achieved. The competition again takes place on a steep, heavily moguled course, stressing technical turns, aerial maneuvers and speed.

Right: *Sample judge's scorecard for Turns.*

Below: *Sample judge's scorecard for Airs.*



Bib#	Name	M	L	Qual	Final 1 2	2

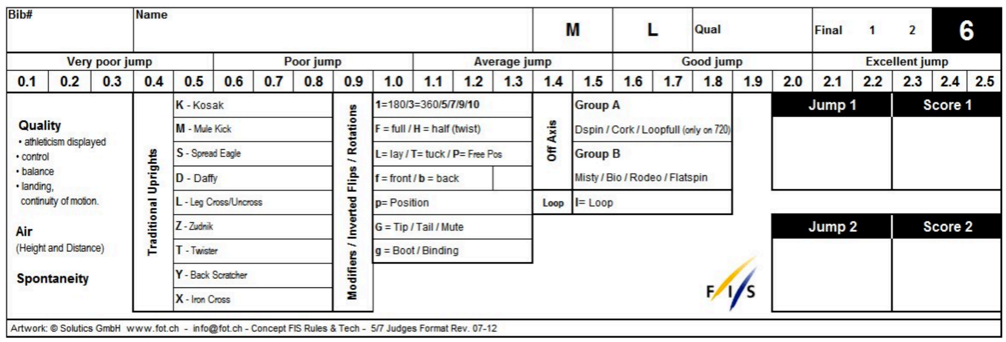
CA	Abs	UB	Turn Evaluation - MOGULS	
			Excellent	4.6 - 5.0
			Very Good	4.1 - 4.5
			Good	3.6 - 4.0
			Above Average	3.1 - 3.5
			Competent	2.6 - 3.0
			Below Average	2.1 - 2.5
			Poor	1.1 - 2.0
			Very Poor	0.1 - 1.0

Deduction	
0.1 - 0.5	L. touchdown, s. stumble., fall line dev., sp check, double pole plant
0.6 - 0.7	Medium touch, no stop
0.8 - 1.0	Hard touch, Sig. Sliding, front roll no stop
1.1 - 1.4	Complete fall without , Slide to near stop
1.5	Any complete stop

Total Score

Artwork: © Solutics GmbH www.fot.ch - info@fot.ch - Concept FIS Rules & Tech - 5/7 Judges Format Rev. 07-2012

Beginning in the 2018-2019 season dual mogul competition will be judged using the same format as the single mogul event. Simply stated, the two competitors will be judged independently of each other using a single run format. The higher score will advance to the next round until a winner is declared.



Bib#	Name	M	L	Qual	Final 1 2	6

Very poor jump					Poor jump					Average jump					Good jump					Excellent jump				
0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5

Quality
- athleticism displayed
- control
- balance
- landing, continuity of motion.

Air (Height and Distance)

Spontaneity

Traditional Uprights	Modifiers / Inverted Flips / Rotations	Off Axis
K - Kosak	1=180/3=360/5/7/9/10	Group A
M - Mule Kick	F = full / H = half (twist)	Dspin / Cork / Loopfull (only on 720)
S - Spread Eagle	L= lay / T= tuck / P= Free Pos	Group B
D - Daffy	f = front / b = back	Misty / Bio / Rodeo / Flatspin
L - Leg Cross/Uncross	p= Position	Loop: l= Loop
Z - Zudnik	G = Tip / Tail / Mute	
T - Twister	g = Boot / Binding	
Y - Back Scratcher		
X - Iron Cross		

Jump 1	Score 1

Jump 2	Score 2

Artwork: © Solutics GmbH www.fot.ch - info@fot.ch - Concept FIS Rules & Tech - 5/7 Judges Format Rev. 07-12

SECTION #2

THE COURSES

The Courses

Mogul courses are different from venue to venue but all adhere to specific minimum or maximum criteria. Course length ranges from 200-275 meters with an average slope grade of 26 degrees. Moguls are set approximately 3.5 meters apart and the course contains two small jumps used for aerial acrobatics (Federation International de Ski, 2017).

Code	Mogul Course Criteria 4200	Measurement
CW (m)	Course Width	18m minimum
TW (m)	Track Width	10m ± 2m
CL (m)	Course Length	235m ± 35m
CF (m)	Control Gate to Fence	2m minimum
SJ (m)	Start to Judges Stand	300m maximum
VD (m)	Vertical Drop Start to Finish	110m ± 30m
HD (m)	Horizontal Distance	175m ± 35m
CA (°)	Course Angle	28° ± 4°
A1 (m)	Start to 1st Air Bump	15% of CL
A2 (m)	2nd Air Bump to Finish Line	20% of CL
FL (m)	Finish Area Length	35m ± 5m
FA (°)	Finish Area Angle	5° ± 5°
No section of the course longer than 20m, shall be less then 20° or greater than 37°		
Minimum length of course for World Championships is 225 m and Winter Olympic Games is 250m		
	ICR 4202.1.4.6 Air Bump Criteria and Specification	
JL (m)	Maximum Distance - last bump to the takeoff (m)	4.0m - 5.0m
LZ (m)	Maximum Distance - takeoff to end of landing (m)	15.0m
AH (cm)	Air Bump Height (cm)	50cm - 60cm
LA (°)	Landing Zone Angle (LA) in degrees (°)	Greater than 26°
TA (°)	Takeoff Angle in degrees of jump (°)	26° - 30°
AW (cm)	Air Bump Width (not less than in cm)	120cm

Above: World Cup course standards for Freestyle Mogul Skiing as set by the FIS.

SECTION #3

SPORT DETAILS

Equipment

Freestyle ski equipment differs slightly from normal alpine skiing equipment.

Skis

Mogul skis usually have no or a minimal side cut and are narrower since edge transition occurs very rapidly; approximately 3-4 times per second (Sands & Bullock, Acclerometry of Mogul Skiers, 2018). Mogul skis are stiff behind the binding and more flexible towards the tip to enable the skier to keep a stable body position and absorb the forces induced by travel over bumps.

Poles

The general rule in recreational skiers for choosing the correct pole length suggests a 90° angle between upper arm and forearm when holding the pole. Ski poles are available in different widths and can be semi-flexible to stiff. Mogul poles are shorter than those of the average skier. They commonly measure between 95cm and 115cm in WC mogul skiers. Pole length is established as the skier stands in a valley between two bumps and places the pole atop the bump in front.

Boots

Mogul ski boots have rigid soles and attach to the binding both at the toe and heel. Boots are available in various degrees of stiffness or flex depending upon athlete anthropometry, skiing technique, and ability. Many athletes modify stock boots using custom foot beds, liners, and heating elements.

Bindings

Bindings consist of a heel piece and toe piece. Bindings have built in safety features that allow them to release through the application of force that pulls up on the heel or torque that rotates the foot. The amount of force required to release a binding can be adjusted based upon athlete anthropometry, skiing technique, and ability. This setting is known as the Deutsches Institut or more commonly as the DIN. Finally, many mogul skiers opt to ski using a binding that has a pivoting heel piece.

Technique

During a mogul run the skis should stay together to act synchronously. The essential movements include the bending of the legs to absorb the mogul and the active extension of the legs immediately after crossing the mogul so as to push the ski tips into the next void separating the bumps. Eccentric back extension also plays a pivotal role as the athlete impacts the bump and crosses over its crest (Sands & Bullock, EMG of Mogul Skiers, 2018). The poles are set alternately onto the backside of the mogul very quickly and should remain in front of the body to avoid inefficient movements with the arms (Kurpiers, Dynamics of Freestyle Skiing, 1994, p. 30).

Uniforms

Currently held belief among the mogul skiing community is that a white uniform will camouflage mistakes made by the skier and therefore improve the final score for the competitor. Additionally, in observations made by the author, it is not uncommon to see athletes modify the knee patch using tape, marker, or paint to improve judging perception. Given the anecdotal nature of the authors observations some further investigation was warranted. Using data collected throughout the 2018-2019 season Sands and Bullock (Moguls Uniform Study, 2019) categorized skiers into four different categories and aggregated the turn scores from the top 24 skiers from each gender on the World Cup. The analyses were collapsed across gender (N=48).

The four categories include: light or dark uniform, light or dark patches, patches worn high (above the midline of the tibia) or low (below midline of the tibia) and large (those that cover more than one half the tibial length) or small patches (those that cover less than one half the tibial length). When categorizing athletes, video review was used while the athlete was at approximately 90 degrees of knee flexion with a front facing view; just as the judges stand at the World Cup is positioned.

All data was analyzed chi square using SPSS "Cross Tabs" procedure. Results of the analysis are in the graphs below.

Pant Color: Light vs Dark

Crosstab

			PantsL1D2		
			1	2	Total
All Median Groups	1	Count	10a	2a	12
		% within PantsL1D2	27.8%	16.7%	25.0%
	2	Count	7a	5a	12
		% within PantsL1D2	19.4%	41.7%	25.0%
	3	Count	11a	1a	12
		% within PantsL1D2	30.6%	8.3%	25.0%
	4	Count	8a	4a	12
		% within PantsL1D2	22.2%	33.3%	25.0%
Total		Count	36	12	48
		% within PantsL1D2	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of PantsL1D2 categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.444[a]	3	.217
Likelihood Ratio	4.710	3	.194
Linear-by-Linear Association	.087	1	.768
N of Valid Cases	48		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is 3.00.

The images above display the statistical analysis for pant color (light or dark) category. Pant color fails to differentiate between median scores or groups (Sands & Bullock, Moguls Uniform Study, 2019).

Patch Color: Light vs. Dark

Crosstab

			PatchShadeD1L2 1	PatchShadeD1L2 2	Total
All Median Groups	1	Count	10a	2a	12
		% within PatchShadeD1L2	27.8%	16.7%	25.0%
	2	Count	7a	5a	12
		% within PatchShadeD1L2	19.4%	41.7%	25.0%
	3	Count	11a	1a	12
		% within PatchShadeD1L2	30.6%	8.3%	25.0%
	4	Count	8a	4a	12
		% within PatchShadeD1L2	22.2%	33.3%	25.0%
Total		Count	36	12	48
		% within PatchShadeD1L2	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of PatchShadeD1L2 categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.444[a]	3	.217
Likelihood Ratio	4.710	3	.194
Linear-by-Linear Association	.087	1	.768
N of Valid Cases	48		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is 3.00.

The images above display the statistical analysis for patch color (light or dark) category. Patch color fails to differentiate between median scores or groups (Sands & Bullock, Moguls Uniform Study, 2019).

Patch Size: Small vs. Large

Crosstab

			PatchSizeS1L2 1	PatchSizeS1L2 2	Total
All Median Groups	1	Count	8a	4a	12
		% within PatchSizeS1L2	27.6%	21.1%	25.0%
	2	Count	6a	6a	12
		% within PatchSizeS1L2	20.7%	31.6%	25.0%
	3	Count	10a	2a	12
		% within PatchSizeS1L2	34.5%	10.5%	25.0%
	4	Count	5a	7a	12
		% within PatchSizeS1L2	17.2%	36.8%	25.0%
Total		Count	29	19	48
		% within PatchSizeS1L2	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of PatchSizeS1L2 categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	5.140[a]	3	.162
Likelihood Ratio	5.417	3	.144
Linear-by-Linear Association	.426	1	.514
N of Valid Cases	48		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is 4.75.

The images above display the statistical analysis for patch size (small or large) category. Patch size fails to differentiate between median scores or groups (Sands & Bullock, Moguls Uniform Study, 2019).

Patch Size: High vs. Low

Crosstab

			PatchPosH1L2 1	PatchPosH1L2 2	Total
All Median Groups	1	Count	7a	5a	12
		% within PatchPosH1L2	23.3%	27.8%	25.0%
	2	Count	6a	6a	12
		% within PatchPosH1L2	20.0%	33.3%	25.0%
	3	Count	9a	3a	12
		% within PatchPosH1L2	30.0%	16.7%	25.0%
	4	Count	8a	4a	12
		% within PatchPosH1L2	26.7%	22.2%	25.0%
Total		Count	30	18	48
		% within PatchPosH1L2	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of PatchPosH1L2 categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.778[a]	3	.620
Likelihood Ratio	1.802	3	.615
Linear-by-Linear Association	.627	1	.429
N of Valid Cases	48		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is 4.50.

The images above display the statistical analysis for patch position (high or low) category. Patch size fails to differentiate between median scores or groups (Sands & Bullock, Moguls Uniform Study, 2019).

In short, uniform selection has negligible effect on turn scores in the sport of freestyle moguls skiing (Sands & Bullock, Moguls Uniform Study, 2019). Athletes should be advised to focus their efforts on other areas of performance while ensuring comfort and confidence are not compromised through uniform selection and modification.

Qualification

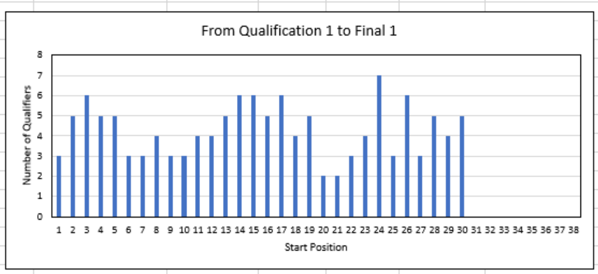
Current single mogul competition is comprised of three rounds of competition. The rounds are entitled Qualification 1 (Q1), Final 1 (F1), and Final 2 (F2). In Q1 all athletes compete. Start list order is randomized for those whose current FIS World Cup rank is between 1 and 30. Those athletes occupy the first 30 start positions in random order. Those outside the top 30 are randomized beginning with start position number 31 through the remainder of the field.

Competition begins with Q1 and each athlete in the field has the opportunity to complete one run to be judged using the criteria stated above. Upon completion of Q1, the top 16 qualification scores are seeded in reverse order, lowest to highest score for F1. The remainder of the field in done competing for the event. After elimination, competition continues with F1 in which the remaining 16 athletes again have the opportunity to complete one run to be judged using the same criteria. Upon completion of F1, the field is narrowed for F2. In F2, the top 6 qualification scores from F1 are seeded in reverse order one final time, lowest to highest score. The six remaining athletes ski one final time in front of the judges until winner is declared. This process applies to both male and female single mogul competition.

Given the current mogul format, coaches and athletes should consider the odds of advancement and make tactical decisions whereby the competitor has the best opportunity to advance to the next round. In an attempt to classify qualifiers from non-qualifiers an analysis of the 2018-2019 data was undertaken by Bullock and Sands (Analysis of Single Mogul Start List Order, 2019) in which non-parametric tests were divided into two categories: 1) Nominal (group) and 2) Ordinal (start list). Two hypothesis were then developed: H0) both groups have the same start orders and H1) groups differ in their start orders.

From Qualification 1 to Final 1

	Ruka Start List	Thaiwoo Start List	Calgary Start List	Lake Placid Start List	Tremblant Start List	Tazawako Start List	Shymbulak Start List	Deer Valley Start List	Total List
1	1	1	1	1	1	1	1	1	3
2	2	2	2	2	2	2	2	2	5
3	3	3	3	3	3	3	3	3	6
4	4	4	4	4	4	4	4	4	5
5	5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6	3
7	7	7	7	7	7	7	7	7	3
8	8	8	8	8	8	8	8	8	4
9	9	9	9	9	9	9	9	9	3
10	10	10	10	10	10	10	10	10	3
11	11	11	11	11	11	11	11	11	4
12	12	12	12	12	12	12	12	12	4
13	13	13	13	13	13	13	13	13	5
14	14	14	14	14	14	14	14	14	6
15	15	15	15	15	15	15	15	15	6
16	16	16	16	16	16	16	16	16	5
17	17	17	17	17	17	17	17	17	6
18	18	18	18	18	18	18	18	18	4
19	19	19	19	19	19	19	19	19	5
20	20	20	20	20	20	20	20	20	2
21	21	21	21	21	21	21	21	21	2
22	22	22	22	22	22	22	22	22	3
23	23	23	23	23	23	23	23	23	4
24	24	24	24	24	24	24	24	24	7
25	25	25	25	25	25	25		25	3
26	26	26	26	26	26	26		26	6
27	27	27	27	27	27			27	3
28	28	28	28	28	28			28	5
29	29	29	29	29	29			29	4
30	30	30	30	30	30			30	5
31	31	31	31	31	31			31	0
32	32		32	32	32			32	0
33	33		33	33	33			33	0
34	34		34	34	34			34	0
35			35	35	35				0
36			36	36	36				0
37			37	37					0
38			38						0



Total List Women

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	8	21.1	21.1	21.1
	2	2	5.3	5.3	26.3
	3	8	21.1	21.1	47.4
	4	6	15.8	15.8	63.2
	5	8	21.1	21.1	84.2
	6	5	13.2	13.2	97.4
	7	1	2.6	2.6	100
	Total	38	100	100	

Ranks

	Group	N	Mean Rank	Sum of Ranks
Qual 1 to Final 1	Qualfied	130	119.38	15519
	Not Qualitifed	130	141.62	18411
	Total	260		

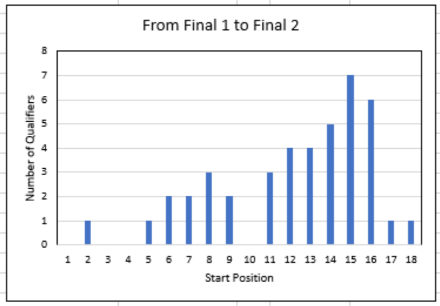
Earlier in Line Up is Better

Test Statistics

	Qual 1 to Final 1	
Mann-Whitney U	7004	
Wilcoxon W	15519	
Z	-2.386	
Asymp. Sig. (2-tailed)	0.017	Statistically Different

Left: Graphical display of FIS World Cup Women's Q1 to F1 qualification rate. Note that earlier in the line-up is better. Zero athletes outside of the top 30 FIS World Cup rank were able to advance from Q1 to F1.

	From Final 1 to Final 2							
	Ruka	Thaiwoo	Calgary	Lake Placid	Tremblant	Shymbulak	Deer Valley	
	Start List	Start List	Start List	Start List	Start List	Start List	Start List	Total List
1	1	1	1	1	1	1	1	0
2	2	2	2	2	2	2	2	1
3	3	3	3	3	3	3	3	0
4	4	4	4	4	4	4	4	0
5	5	5	5	5	5	5	5	1
6	6	6	6	6	6	6	6	2
7	7	7	7	7	7	7	7	2
8	8	8	8	8	8	8	8	3
9	9	9	9	9	9	9	9	2
10	10	10	10	10	10	10	10	0
11	11	11	11	11	11	11	11	3
12	12	12	12	12	12	12	12	4
13	13	13	13	13	13	13	13	4
14	14	14	14	14	14	14	14	5
15	15	15	15	15	15	15	15	7
16	16	16	16	16	16	16	16	6
	17	17	17	17	17	17	17	1
	18	18	18	18	18	18	18	1



Total List

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	4	10.5	22.2	22.2
	1	4	10.5	22.2	44.4
	2	3	7.9	16.7	61.1
	3	2	5.3	11.1	72.2
	4	2	5.3	11.1	83.3
	5	1	2.6	5.6	88.9
	6	1	2.6	5.6	94.4
	7	1	2.6	5.6	100
	Total	18	47.4	100	
Missing	System	20	52.6		
Total		38	100		

	Ranks	Percent	
Line Up 11-16	29	74.359	Chance to qualify Final 1 to Final 2
Line up 5-10	10	25.641	Chance to qualify Final 1 to Final 2
Total Ranks	39		

Ranks

	Group	N	Mean Rank	Sum of Ranks
Final 1 to Final 2	Qualfied	42	82.6	3469
	Not Qualified	72	42.86	3086
	Total	114		

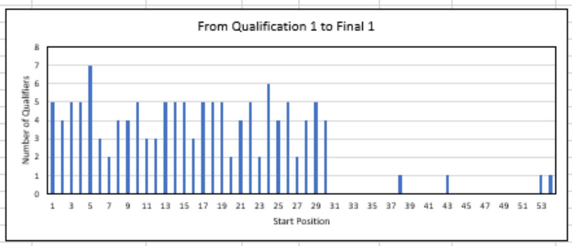
Later in Line Up is Better

Test Statisticsa

	Final 1 to Final 2	
Mann-Whitney U	458	
Wilcoxon W	3086	
Z	-6.203	
Asymp. Sig. (2-tailed)	0	Statistically Different

Left: Graphical display of FIS World Cup Women's F1 to F2 qualification rate. Note in this case that later in the line-up is better. Athletes who failed to qualify 11-16 (top-6 in Q1) in the line-up saw their chances of advancement for F1 to F2 decrease from 74.3% to 25.6%. Only one athlete throughout the 2018-2019 season qualified who qualified in a position less than 11 was able to reach F2.

	From Qualification 1 to Final 1								
	Ruka	Thaiwoo	Calgary	Lake Pla	Tremblar	Tazawak	Shymbul	Deer Valley	
	Start List	Start List	Start List	Start List	Start List	Start List	Start List	Start List	Total List
1	1	1	1	1	1	1	1	1	5
2	2	2	2	2	2	2	2	2	4
3	3	3	3	3	3	3	3	3	5
4	4	4	4	4	4	4	4	4	5
5	5	5	5	5	5	5	5	5	7
6	6	6	6	6	6	6	6	6	3
7	7	7	7	7	7	7	7	7	2
8	8	8	8	8	8	8	8	8	4
9	9	9	9	9	9	9	9	9	4
10	10	10	10	10	10	10	10	10	5
11	11	11	11	11	11	11	11	11	3
12	12	12	12	12	12	12	12	12	3
13	13	13	13	13	13	13	13	13	5
14	14	14	14	14	14	14	14	14	5
15	15	15	15	15	15	15	15	15	5
16	16	16	16	16	16	16	16	16	3
17	17	17	17	17	17	17	17	17	5
18	18	18	18	18	18	18	18	18	5
19	19	19	19	19	19	19	19	19	5
20	20	20	20	20	20	20	20	20	2
21	21	21	21	21	21	21	21	21	4
22	22	22	22	22	22	22	22	22	5
23	23	23	23	23	23	23	23	23	2
24	24	24	24	24	24	24	24	24	6
25	25	25	25	25	25	25	25	25	4
26	26	26	26	26	26	26	26	26	5
27	27	27	27	27	27	27	27	27	2
28	28	28	28	28	28	28	28	28	4
29	29	29	29	29	29	29	29	29	5
30	30	30	30	30	30	30	30	30	4
31	31	31	31	31	31	31	31	31	0
32	32	32	32	32	32	32	32	32	0
33	33	33	33	33	33	33	33	33	0
34	34	34	34	34	34	34	34	34	0
35	35	35	35	35	35	35	35	35	0
36	36	36	36	36	36	36	36	36	0
37	37	37	37	37	37	37	37	37	0
38	38	38	38	38	38	38	38	38	1
39	39	39	39	39	39	39	39	39	0
40	40	40	40	40	40	40		40	0
41	41	41	41	41	41	41		41	0
42	42	42	42	42	42	42		42	0
43	43	43	43	43	43	43		43	1
44	44	44	44	44	44	44		44	0
45	45	45	45	45	45				0
46	46	46	46	46	46				0
47	47	47	47	47	47				0
48	48	48	48	48	48				0
49	49	49	49	49	49				0
50	50		50	50	50				0
51	51		51	51	51				0
52	52		52	52	52				0
53	53		53	53	53				1
54	54		54	54	54				1
55	55		55	55	55				



Total List Men

		Frequen	Percent	Valid Perce	Cumulative Percent
Valid	0	20	37.7	37.7	37.7
	1	4	7.5	7.5	45.3
	2	4	7.5	7.5	52.8
	3	4	7.5	7.5	60.4
	4	7	13.2	13.2	73.6
	5	12	22.6	22.6	96.2
	6	1	1.9	1.9	98.1
	7	1	1.9	1.9	100
	Total	53	100	100	

Ranks

	Group	N	Mean Rank	Sum of Ranks
Qual 1 to Final 1	Qualified	112	110.3	12353.5
	Not Qualified	243	209.2	50836.5
	Total	355		

Earlier in Line Up is Better

Test Statistics

	Qual1 to Final 1	
Mann-Whitney U	6025.5	
Wilcoxon W	12353.5	
Z	-8.44	
Asymp. Sig. (2-tail	0	Statistically Different

Ranks — Top 30 Only

	Group	N	Mean Rank	Sum of Ranks
Qual to Final 1	Qualified	126	118.09	14879
	Not Qualified	114	123.17	14041
	Total	240		

No effect from Line Up Position

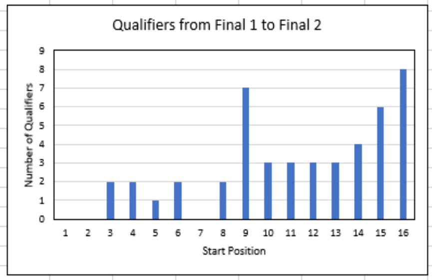
Test Statisticsa

	Group	
Mann-Whitney U	6878	
Wilcoxon W	14879	
Z	-0.566	
Asymp. Sig. (2-tail	0.571	Not Statisically Different

Left: Graphical display of FIS World Cup Men's Q1 to F1 qualification rate. Note that earlier in the line-up is better. Four athletes outside of the top 30 FIS World Cup rank were able to advance from Q1 to F1.

From Final 1 to Final 2

Ruka Start List	Thaiwoo Start List	Calgary Start List	Lake Placid Start List	Tremblant Start List	Tazawako Start List	Shymbula Start List	Deer Valley Start List	Total List
1	1	1	1	1	1	1	1	0
2	2	2	2	2	2	2	2	0
3	3	3	3	3	3	3	3	2
4	4	4	4	4	4	4	4	2
5	5	5	5	5	5	5	5	1
6	6	6	6	6	6	6	6	2
7	7	7	7	7	7	7	7	0
8	8	8	8	8	8	8	8	2
9	9	9	9	9	9	9	9	7
10	10	10	10	10	10	10	10	3
11	11	11	11	11	11	11	11	3
12	12	12	12	12	12	12	12	3
13	13	13	13	13	13	13	13	3
14	14	14	14	14	14	14	14	4
15	15	15	15	15	15	15	15	6
16	16	16	16	16	16	16	16	8
							17	
							18	



Start Positions	13-16	9-12	5-8
Sum of Positions	46		

	13-16	9-12	4-8
Qualifier vs Non	21	16	5
Percentage	45.6522	34.7826	10.8696

Ranks

	Group	N	Mean Rank	Sum of Ranks
Final 1 to Final 2	Qualified	42	75.17	3157
	Not Qualified	70	45.3	3171
	Total	112		

Later in Line Up is Better

Test Statisticsa	Final 1 to Final 2	
	Final 1 to	
Mann-Whitney U	686	
Wilcoxon W	3171	
Z	-4.721	
Asymp. Sig. (2-tailed)	0	Statistically Different

Left: Graphical display of FIS World Cup Men's F1 to F2 qualification rate. Note in this case that later in the line-up is better. Athletes who failed to qualify 9-16 (top-8 in Q1) in the line-up saw their chances of advancement for F1 to F2 decrease from 88.2% to 10.8%. Only five athletes throughout the 2018-2019 season qualified who qualified in a position less than 9 was able to reach F2.

SECTION #4

INJURIES

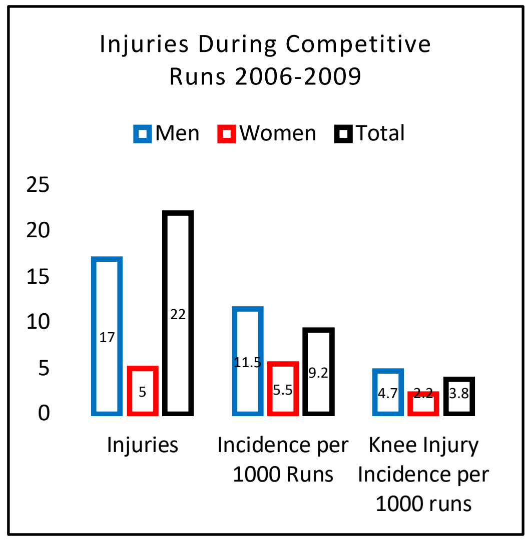
Incidence

In data taken from the 2006 to 2009 seasons, among all freestyle skiing events moguls/dual moguls have a comparatively high injury rate (Florenes, Heir, Nordsletten, & Bahr, 2010). From 2006 to 2009, Florenes et al. (2010) recorded 76 acute injuries in moguls/dual moguls that resulted in at least a one day cessation in training or competition (2010). It is very important to note that these data only include runs completed during World Cup/World Ski Championship competitions and does not include training.

In the same study, 57 of the reported 76 injuries resulted in greater than an eight-day cessation from training or competition while the average loss of time was 24.5 days (Florenes, Heir, Nordsletten, & Bahr, 2010). 28 (37%) of those injures were categorized as severe with a greater than 28 days' cessation in training (Florenes, Heir, Nordsletten, & Bahr, 2010).

Relative injury rate, expressed as the number of injuries per 100 athletes per season, was 32.5 (Florenes, Heir, Nordsletten, & Bahr, 2010).

Injury rates among males and females are noteworthy. Between 2006 and 2009 males were injured at nearly twice the rate with males reporting 154 injuries and women reporting 79 (Florenes, Heir, Nordsletten, & Bahr, 2010). This is likely due to higher volume of participation by males. Florenes et al. (2010) also state the relative rate of injury per 1000 runs in males during the period was 11.5 and 5.5 in females. The relative rate of knee injuries per 1000 runs in males was 4.7 and 2.2 in females.

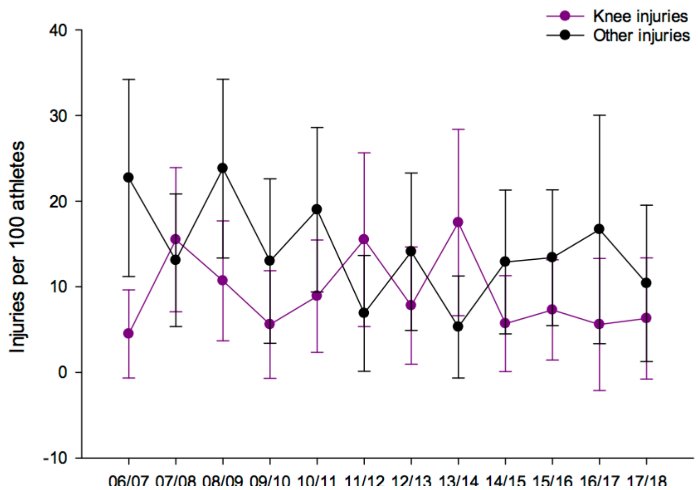


In an earlier study, Heir et al. investigated the incidence and trends of ACL injuries in FIS World Cup freestyle mogul skiing over a ten-year period from the 1992/93 season through the 2001/02 season. In that period 65 ACL injuries occurred within 60.048 skier days, giving an overall rate of 1.23 ACL injuries per 1000 skier days (2003). Furthermore, the risk of ACL injury was 3.8 (women) to 8.0 (men) times higher in competition as compared to training (Heir, Krosshauk, & Ekeland, 2003).

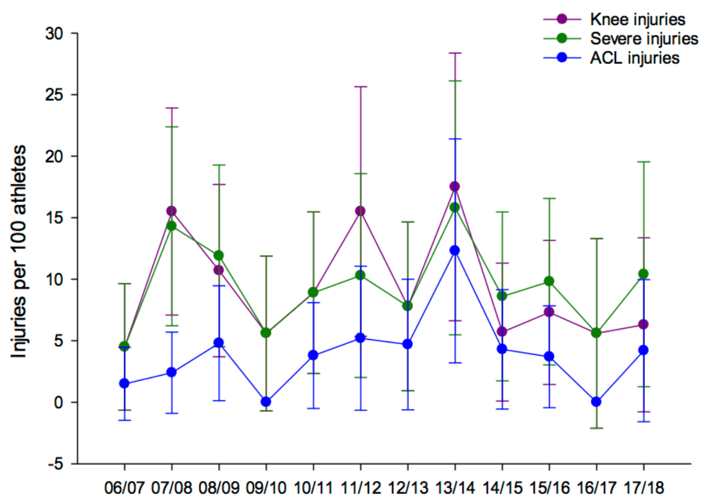
Again, mogul skiing had a significantly higher injury rate as compared to the other freestyle disciplines (Heir, Krosshauk, & Ekeland, 2003). This is important to note for the practitioner as physical preparation has the potential to reduce these incidences.

FIS Data

Data from the FIS (2008) dating back to 2006-2007 season display injury rates for those skiers on the World Cup Tour. In that period, athletes most commonly experienced injuries to the knee (39.2%), the low back, pelvis and sacrum (9%) and the head, face (10.1%). For more detailed information from this literature refer to graphic representation at right and the image below.



Injury rate, expressed as injuries per 100 athletes for injuries to the knee vs other injuries, reported in the mogul discipline for each of the 12 seasons (2006-18).



Injury rate, expressed as injuries per 100 athletes for knee injuries, severe injuries and ACL injuries (all), reported in the mogul discipline for each of the 12 seasons (2006-18).

The Spine

Given the data from the FIS and that collected over 4-year period by US Ski and Snowboard there is a significant interest in the mogul skier's phenomenon known as "Mogul Back". Data from Bullock and Sands (2018) shows a high erector spinae activation as the skier contacts the face of the bump and potentially a second activation if the athlete is in a poor position (the knees are under the hips with the legs extended and the torso pitched forward) as the athlete reaches the peak of the bump. The high velocity and high loads associated with this eccentric muscle action are believed to be related to the Mogul Back phenomenon.

In 2017, Thoreson et al. conducted a study with the objective to investigate the amount of spinal MRI abnormalities and the lifetime prevalence of low back pain (LBP) in 16 young elite mogul skiers compared to 28 non-athletes in the corresponding age in a cross-sectional design. Low back pain was assessed by a questionnaire consisting of a section pertaining to previous or present back pain, the Oswestry disability index, and the EuroQol questionnaire. MRI examinations from T5 to sacrum were conducted to evaluate spinal pathologies.

According to the study by Thoreson et al. (2008), Mogul skiers had significantly more MRI abnormalities (e.g. disc degeneration) in mean (7.25 vs 3.78, P < 0.023) compared to the controls. No significant difference was seen regarding the lifetime LBP prevalence between the groups (50% vs 42%, P = 0.555) and no correlation could be found between disc degeneration and back pain in this study.

<u>Mechanism</u>

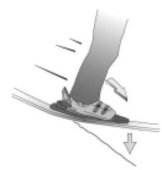
Injuries in freestyle mogul skiing occur due to several different causal factors (McIntyre, 1963). The chart at right is a summary of those factors.

Loss of Control
Poor Physical Condition
Inexperience or Poor Technique
Fatigue
Excessive Speed
Dangerous Course Conditions
Ruts
Obstacles (barriers, markers, etc.)
Variable Quality of Snow
Powdered/Fresh Snow
Ice
Change from Sun to Shade
Temperature Changes
Soft/Slushy Snow
Weather Conditions
Extreme Cold / Heat
Poor Visibility
Sun Exposure
Equipment Malfunction or Failure
Hard Gear Malfunction/Failure
Soft Gear Malfunction/Failure
Lack of Preventative Maintenance
Lack of Equipment Preparation

All mechanisms fall into one of three categories: 1) intrinsic risk factors such as strength, power, fitness level, prior injury history and/or anatomy; 2) extrinsic risk factors such as ruts, obstacles, snow conditions, visibility, weather, equipment factors, and other skiers; and finally, 3) inciting events such as a crash, loss of balance, catastrophic equipment failure, or inefficient body position (Kurpiers, Dynamics of Freestyle Skiing, 1994).

There are three positions that appear to compromise the knee joint specifically as it relates to ligamentous structures (Kurpiers, Dynamics of Freestyle Skiing, 1994).The first is a combined valgus and external rotation which occurs when the skier is falling forward between the skis after catching an inside edge (Kurpiers, Dynamics of Freestyle Skiing, 1994).

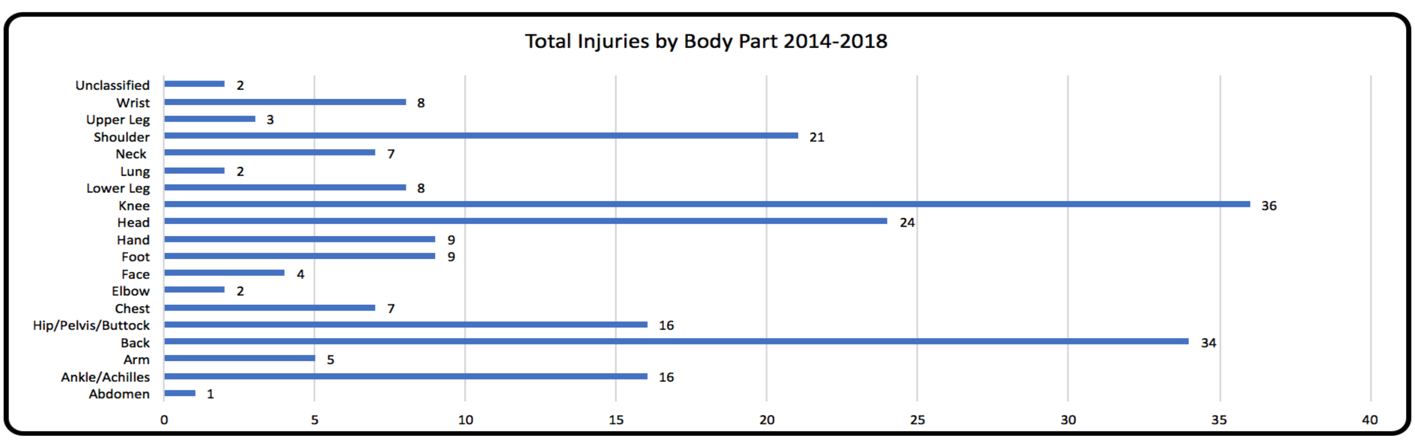
The second mechanism is the boot-induced anterior drawer, which occurs when the boot is forcing the tibia anteriorly when contacting the back of the ski with an almost extended knee. It has been proposed that this is the most frequently encountered injury mechanism to the knee in mogul skiing (Heir, Krosshauk, & Ekeland, 2003).



The third mechanism is known as the phantom-foot phenomenon. This position describes a fall backward between the skis, catching the inside or outside edge of the downhill ski leading to a forced rotation of the knee (Kurpiers, Dynamics of Freestyle Skiing, 1994). Common movements that lead to this position include attempt to get up while moving after a fall, the attempt to recover from an off-balance position, and the attempt to sit down after losing control (Johnson, Ettlinger, & Shealy, 2005).

Types

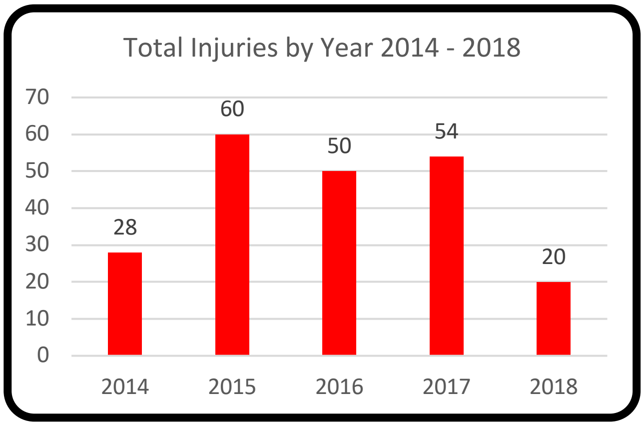
The most common injuries in mogul skiing are to the knee (Heir, Krosshauk, & Ekeland, 2003). In a study from 2001, Heir et al. surveyed 95 FIS Freestyle World Championship skiers. Of those surveyed, 47% had previously sustained one or more major knee injuries and still returned to a high level of athletic performance. One fourth of the skiers had sustained one or more ACL ruptures (Heir, Krosshauk, & Ekeland, 2003). Below is a graph that displays internal data on the number of injuries in US Ski Team members from 2014 to 2018.



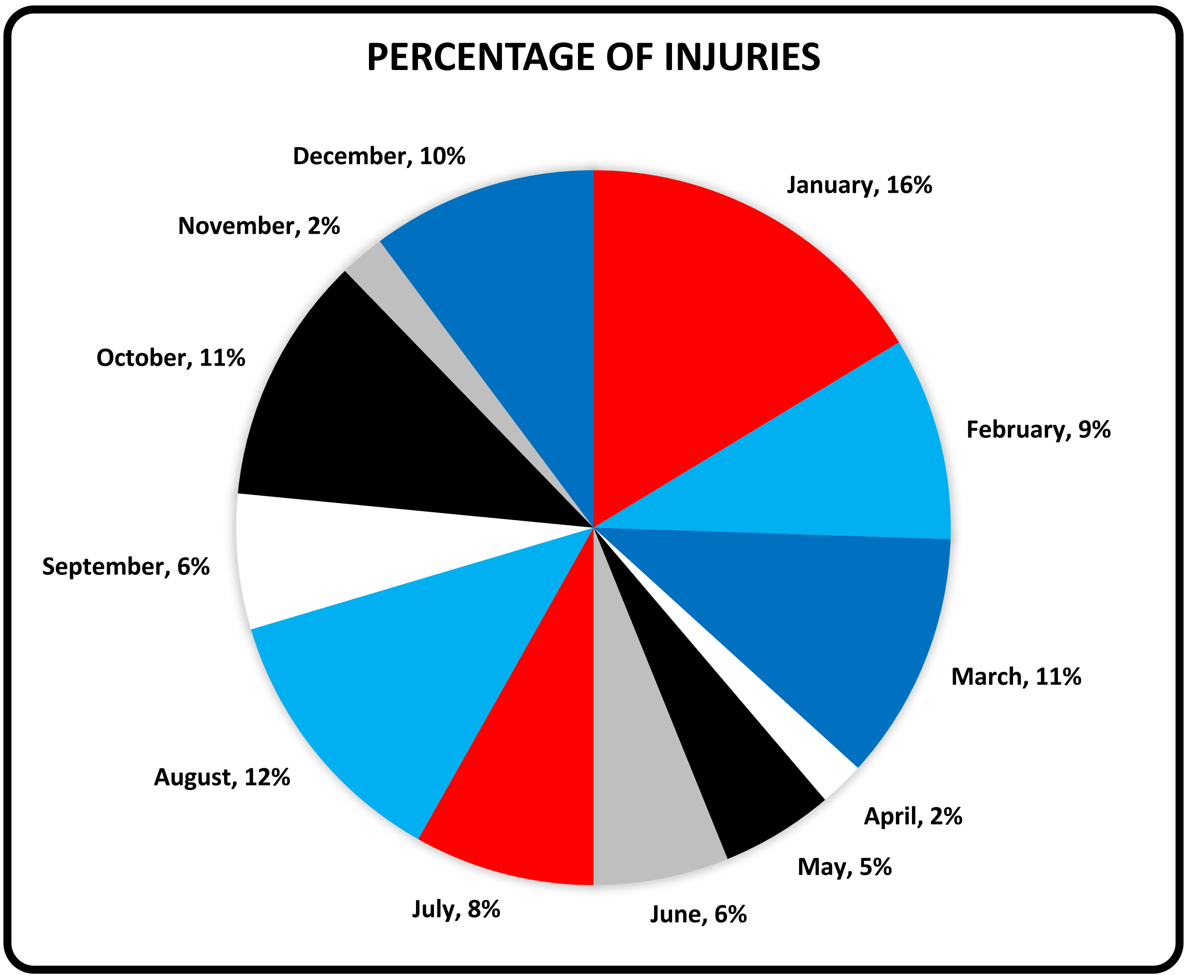
US Ski and Snowboard Data

Disclaimer: When reviewing these data please note that records were poor from January 2014 to August 2014.

Injuries Per Year

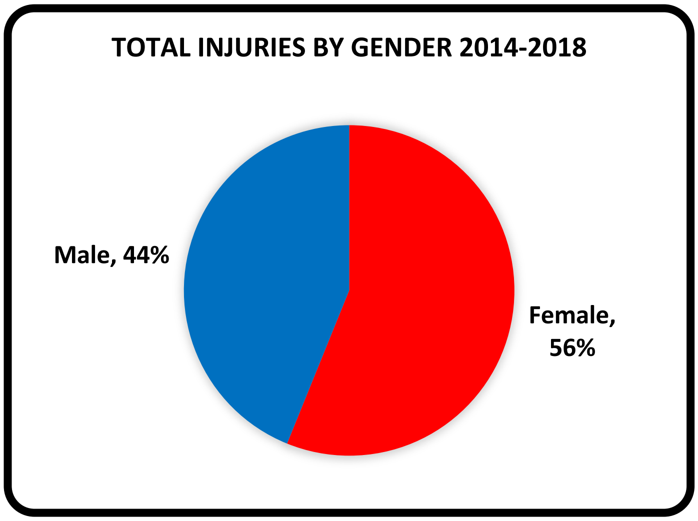


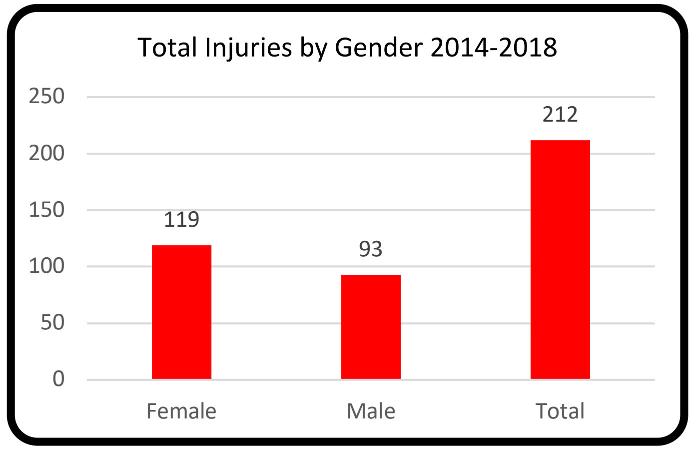
The total number injuries by year ranges from 50-60; in which January has the highest incidence of injury (16%). This is possibly due to the high density of competitions that occur in January (4) and the cessation of training that occurs in late December due to the Christmas holiday. The lowest density of injuries occurs in April (2%). This is likely due to extremely low exposure to competition and training. During April, there is only one training opportunity and zero competitions (Bullock, Incidence of Injury in United States World Cup Mogul Skiers from 2014-2018, 2018).



Injuries by Gender

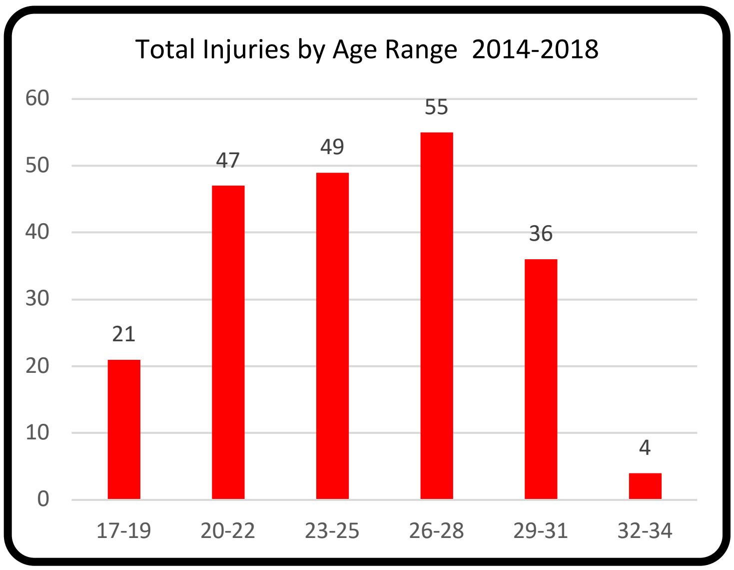
At US Ski and Snowboard, females suffer 56% of the total injuries while males suffer 44%. The total number of injuries reported from January 2014 to September 2014 was 212; 119 of those reported were females and 93 of those reported were from males (Bullock, Incidence of Injury in United States World Cup Mogul Skiers from 2014-2018, 2018).

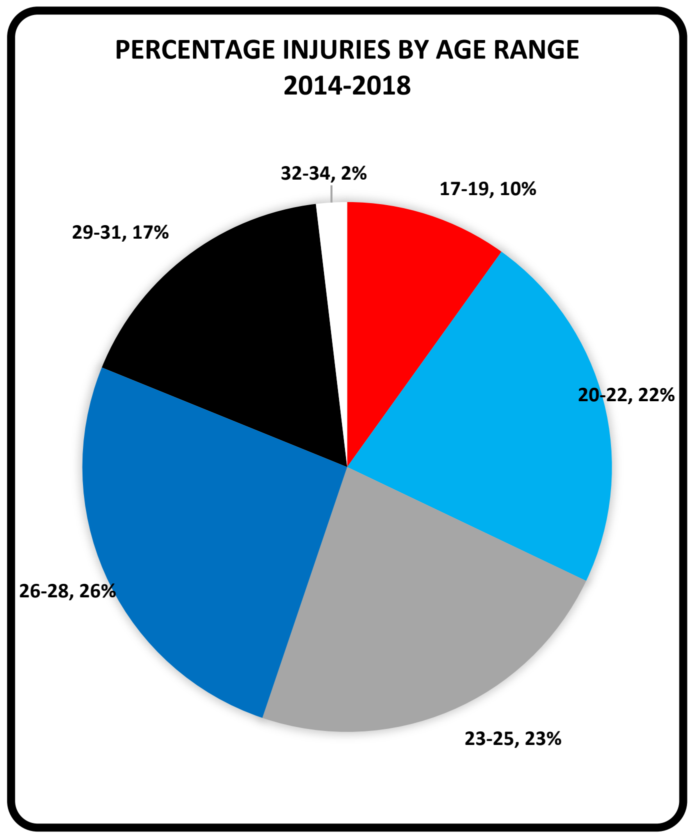




Injuries by Age

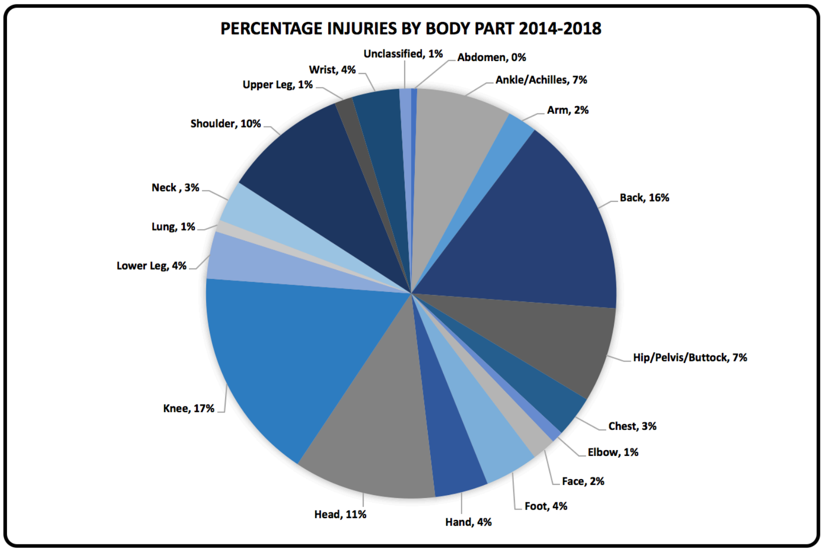
The age of elite level US mogul skiers have ranged from 15 to 34 years of age. Historical data are not known regarding how many total athletes participated at each respective age; thus, making it difficult to discern the incident rate. However, it may be beneficial for the practitioner to be aware of those injuries reported based upon age.



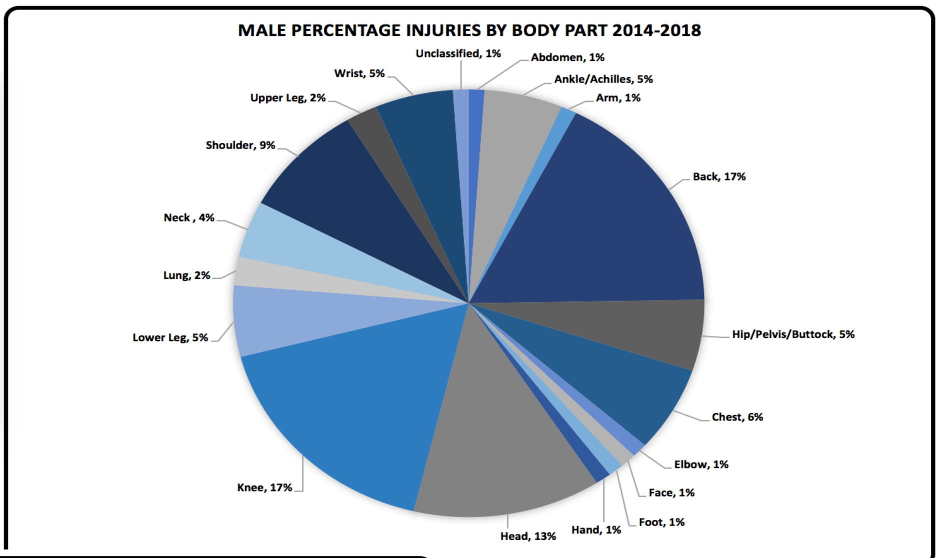


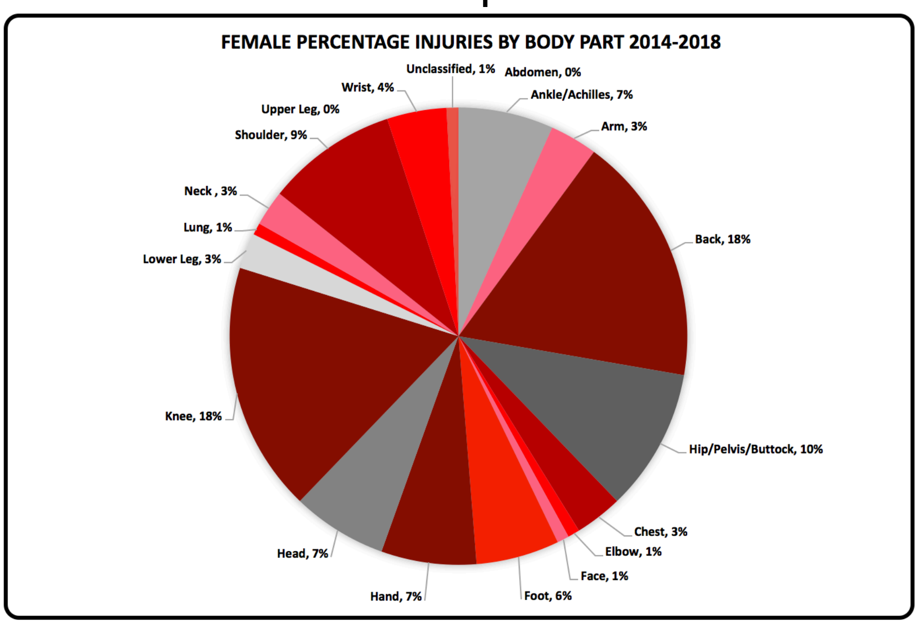
Injuries by Body Region/Part

It has been widely reported in FIS injury data that the most commonly injured joint or body part in mogul skiers is the knee. US Ski and Snowboard is no exception. It does, however appear that organizationally US Ski and Snowboard experiences a lower percentage of injuries to knee than our competitors – 17% as compared to 39.2%. As seen in the data below: the knee remains the most commonly injured body part (17%); followed closely by the back (16%), head (11%), and the shoulder (10%) (Bullock, Incidence of Injury in United States World Cup Mogul Skiers from 2014-2018, 2018).



Gender does appear to play a role in the incidence of injury base upon body part/region. Females seem to experience a higher incidence of injury relative to the knee, and hip complex. While males appear to experience a higher incidence of injury to the head and chest region. All other body parts/regions appear to be injured at a similar rate.





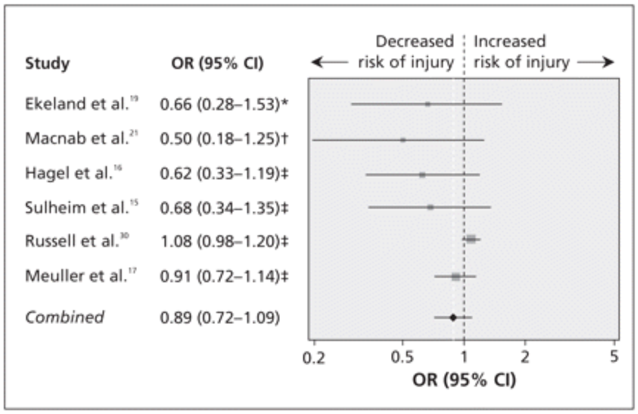
Prevention

In addition to the protective devices listed below, the coaching staff, strength and conditioning practitioner, and athletes can all play in integral role in the prevention of injury. Adhering to principles of specificity, progression, overload, reversibility, variability/variation and consideration of genetic factors can help limit the risk to which the athlete is exposed. More detail on the preparation of athletes can be found in Section #7 entitled Sport and Skill Demands.

Helmets

In a meta-analysis, Russel et al. (2010), concluded the use of helmets had a significant protective effect against head injuries among skiers and snowboarders.

The pooled analysis showed that the risk of head injury was reduced by 35% with helmet use (95% CI 21%–46%) and that 2–5 of every 10 head injuries among helmet users could be prevented (Russell, Christie, & Hagel, 2010). Although not statistically significant, there was some suggestion that helmets had a greater protective effect among males than among females; the reasons for which are not known. These results are like those of other reviews of concussions and use of protective equipment in a variety of summer and winter activities.



It is important to note that literature on this topic has failed to consistently define a head injury. Differences in the findings may be due to the definitions used for severe head injury or to the extent the influence from confounding variables.

Although wearing a helmet reduces the risk of head injury, there is concern that helmets may increase the risk of neck injury due primarily to head:body ratio seen in children and adolescents of different ages. Pooled results from Russell et al. (2010), and other individual studies showed no significant association between helmet use and increased risk of neck injury. This is consistent with biomechanical data showing no increase in neck loads associated with helmet use in simulated snowboarding falls.

Some coaches and athletes have suggested the use of helmets may provide a false sense of security and result in more aggressive or dangerous participation. Several studies have examined risk compensation (risk-taking behavior) in relation to helmet use among skiers. The available evidence suggests that, if helmet users exhibit compensating behavior, their level of injury risk is not higher than that of nonusers (Russell, Christie, & Hagel, 2010).

Back Protection

Currently, there is only one published study on the use of back protectors in winter sports. That study was performed on snowboarders with seemingly inapplicable results. However, many studies do exist on the use of back protection in motor sports.

To prevent injuries to the spine and back, various back protectors are commercially available. However, to assess the protective potential of current protectors, the only international standard available that refers to testing back protectors was developed for the safety gear of motorcyclists. Lacking an alternative, the standard is used by many manufacturers of snow sports protectors, although it is questionable whether the requirements of this standard are also applicable to snow sports.

Protector		Drop test, EN1612				Penetration test, EN1077	
Design		Thickness (mm)	F (kN)	F average (kN)	Safety level	(Class A) remaining distance (mm) at 37.5 cm	(Class B) remaining distance (mm) at 75 cm
A	Soft shell	23	**7.3**/ 6.6/6.2	6.7	2	Failure	–
B	Soft shell	23	9.9/ 10.4/**10.9**	10.4	1	Failure	–
C	Backpack protector	22	**17.1**/ 12.2/14.4	14.6	1	6	Failure
D	Soft shell	21	7.8/7.7/**7.9**	7.8	2	3.5	Failure
E	Hard shell	26	**7.8**/6.7/6.8	7.1	2	13	7.5
F	Backpack with jumper	45	8.6/**8.6**/8.4	8.5	2	Failure	–
G	Soft shell	24	**17.2**/14.7/14.3	15.4	1	Failure	–
H	Soft shell	23	6.5/**7.5**/6.8	6.9	2	Failure	–
I	Hard shell	30	**32.5**/12.4/12.1	19.0	None	12.5	5.5
J	Hard shell	23	24.7/**24.9**/22.6	24.1	None	4	Failure
K	Backpack protector	28	5.4/6.7/**10.0**	7.4	2	8	1
L	Hard shell	17	**15.0**/11.5/11.6	12.7	1	Failure	–
M	Protection shirt	14	**50.0**/40.0/NA	45.0	None	Failure	–

All results of the three force measurements are reported; the maximum force is shown in bold. In addition, the average force is given. Safety levels 1 and 2 refer to the threshold values defined in EN1621. 'Failure' denotes complete penetration; otherwise, the penetration depth is given.
F, failure.

Evidently, there is a mismatch between the expectations of athletes, the potential offered by the protector, and the means to test this potential, that is, a performance standard (Schmitt, Liechti, Michel, Sampfli, & Bruhwiler, 2010).

Results of the study demonstrate, only three configurations (see image above) failed the motorcycle standard, and half achieved safety level 2. It was found that different designs are capable of dissipating energy in case of a direct impact such that the requirements are met. Protectors using a soft-shell approach performed better with respect to dissipating energy, but other products (including a backpack filled with a pullover jacket) passed the test. Hard shell designs, in contrast, offered better protection in the penetration test. From an engineering point of view, it should be possible to meet both standards (Schmitt, Liechti, Michel, Sampfli, & Bruhwiler, 2010).

Even though the recent literature does not show any indications that such protectors might cause harm or represent an additional injury risk, the situation is unsatisfactory. A false feeling of safety may be generated in the wearer of a given protector. To improve the situation, basic research concerning the mechanism of spinal injuries is needed, since the biomechanical understanding of the issues appears to be rather weak. It remains debatable whether a special or modified standard for protectors designed for snow sports is needed (Schmitt, Liechti, Michel, Sampfli, & Bruhwiler, 2010).

ACL Protection

Current best practices in anterior cruciate ligament (ACL) rupture prevention involve an understanding of the mechanisms of injury, preceding physical preparation, and monitoring of athlete load accompanied by appropriate volume and intensity adjustment by the coaching staff. In addition to the previously stated skiing related mechanisms of injury several others have been reported in the literature; these include (Hashemi, et al., 2010):

1) Anterior shear force mechanism
2) Axial compressive load mechanism
3) Hyperextension mechanism
4) Valgus collapse mechanism
5) Tibial internal rotation mechanism
6) Combined valgus and anterior shear
7) Combined valgus and internal tibial torque
8) Valgus and external tibial torque
9) Valgus, anterior tibial shear, and axial torque about the long axis of the tibia
10) The hip extension, knee flexion paradox, which includes a combination of delayed or slow co-activation of the quadriceps and hamstrings, a dynamic ground reaction force applied while the knee is near full extension, a shallow medial tibial plateau and a steep posterior tibial slope, and a stiff landing due to incompatible hip and knee flexion velocities.

Appropriate load management enables players to be physically prepared for the demands of training and competition as well as reduce the occurrence of both injury and illness (Wing, 2018). Gabbett (2016) states that exposure to appropriately planned chronic load actually aids to protect against increases in acute load and provides athletes with a protective effect of training against injury. These heightened levels of fitness can only be developed through increased exposure to training (i.e., chronic load).

The benefits of exposing athletes to intense training is strongly supported in the literature. Chronic intense training is not the only factor for coaches to consider, however; Gabbett et al. (2016), have described how high training loads alone are not the issue, how you get there is. There is currently a shift away from total training load and toward acute spikes in training.

It is important that an athlete is physically prepared for the demands of training and sport though exposure to training loads, which both increase performance and reduce injury. This may be best achieved through moderate workloads, with an approximately moderate increase in load, which allows the athlete to benefit from a protective element of training.

Currently there are several data collection methods that can be used, each with their own strengths and weaknesses. They include: 1) session rating of perceived exertion (sRPE), 2) global positioning systems (GPS), 3) heart rate training impulse (TRIMP), and 4) wellness questionnaires.

Current practices for US Ski and Snowboard freestyle mogul skiing include: 1) sRPE, 2) TRIMP and 3) wellness questionnaires; a practice that is highly supported in the literature allowing coaches to monitor both internal and external load as well as measure a dose response relationship. See appendices for examples of each.

SECTION #5

ENVIRONMENTAL CONDITIONS

Altitude

Freestyle mogul skiing competition and training are frequently held at moderate to high altitude (2000-3500m). Males and females respond very similarly to both acute and chronic altitude exposure (American College of Sports Medicine; American Dietetic Association; Dieticians of Canada, 2000).

Altitude exposure is associated with major changes in cardiovascular function (Naejie, 2010). The initial cardiovascular response to altitude is characterized by an increase in cardiac output with tachycardia, no change in stroke volume, whereas blood pressure may temporarily be slightly increased. After a few days of acclimatization, cardiac output returns to normal, but heart rate remains increased, so that stroke volume is decreased. Pulmonary artery pressure increases without change in pulmonary artery wedge pressure. This pattern is essentially unchanged with prolonged or lifelong altitude sojourns. Ventricular function is maintained, with initially increased, then preserved or slightly depressed indices of systolic function, and an altered diastolic filling pattern. Filling pressures of the heart remain unchanged (Naejie, 2010).

Exercise in acute as well as in chronic high-altitude exposure is associated with a brisk increase in pulmonary artery pressure (Chapman, Stray-Gunderson, & Levine, 1998). The relationships between workload, cardiac output, and oxygen uptake are preserved in all circumstances, but there is a decrease in maximal oxygen consumption, which is accompanied by a decrease in maximal cardiac output. The decrease in maximal cardiac output is minimal in acute hypoxia but becomes more pronounced with acclimatization. This is not explained by hypovolemia, acid-bases status, increased viscosity or polycythemia, autonomic nervous system changes, or depressed systolic function. Maximal oxygen uptake at high altitudes has been modeled to be determined by the matching of convective and diffusional oxygen transport systems at a lower maximal cardiac output (Naejie, 2010).

Chapman et al. (1998) state, upon initial ascent to altitude, blood lactate concentrations are elevated at a given sub-maximal work level but peak

values are essentially unaltered. During more prolonged exposure to hypoxia, a reduction in blood lactate concentration has been reported at both sub-maximal and maximal exercise intensities. This phenomenon has been termed the 'lactate paradox', i.e. despite prevailing hypoxia, lactate accumulation in blood during exercise becomes reduced towards sea level values during sub-maximal exercise (van Hall, Calbet, Sondergaard, & Saltin, 2001). Later detailed studies have demonstrated that the low blood lactate concentration is primarily a function of a reduced net lactate release from the exercising legs (van Hall, Calbet, Sondergaard, & Saltin, 2001).

Muscle strength and maximal muscle power, determined by the force generated during brief (1-5s) maximal muscle static and dynamic contractions, respectively, are generally not adversely affected by acute or chronic altitude exposure as long as muscle mass is maintained (van Hall, Calbet, Sondergaard, & Saltin, 2001). In addition, alpha-motoneuron excitability, nerve and muscle conduction velocity, and neuromuscular transmission are not impaired at altitudes exceeding 4300m. Anaerobic performance during very intense, maximal or supramaximal exercise (e.g., Wingate test) lasting 30s are generally also not adversely affected at altitude. For anaerobic performance assessments lasting longer than 30s, there are conflicting results (Fulco, Rock, & Cymerman, 1998).

Of interest to coaches and athletes, exposure to altitudes higher than 2,500m (8,200ft) may result in fluid losses beyond those associated with any exercise that might be performed (Robson-Ansley, Gleeson, & Ansley, 2013). These losses are the result of increased urine production and high respiratory water losses, accompanied by decreased appetite, which lead to an increased need for fluid intake. Thus, fluid intake at high altitude should be increased to as much as 3 to 4 L per day to assure optimal kidney function (American College of Sports Medicine; American Dietetic Association; Dieticians of Canada, 2000).

Finally, from a training standpoint, research has shown consistently that moderate-altitude living (2500 m) combined with low altitude training (1250 m) results in a significantly greater improvement in maximal oxygen uptake and performance over equivalent sea-level training (Chapman, Stray-Gundersen, & Levine, 1998).

Temperature

Freestyle mogul skiers are frequently exposed to very cold training and competition environments. Humans are considered homeotherms, which means that they can and must maintain a relatively constant core body temperature. When core body temperature deviates more than a few degrees from 37C, physiologic function is altered and the body attempts to maintain a balance between rates of heat loss and heat gain (Cappert, 2002).

When exposed to the cold the body loses heat through the combined effects of radiation, conduction, convection and evaporation. While at rest, exposure to cold temperatures triggers two significant responses (Cappert, 2002): 1) thermogenesis and 2) vasoconstriction. These responses result in increased heat production and reduced heat loss.

Although not yet fully understood the human body appears to be able to acclimate to cold environments. These changes appear to be related to increased peripheral vasoconstriction, increased metabolic heat production and increased skin fold thickness.

The effects of cold on exercise all appear to be related to reduced core body temperature. Reductions appear in the following physical capacities: 1) VO_2 Max, 2) dynamic strength, 3) peak power output, and 4) performance in power related activities such as sprinting and jumping (Cappert, 2002). These are all important considerations for the mogul skier who relies heavily upon strength and power to compete at a high level.

The strength and conditioning practitioner should be aware of the following considerations in assisting athletes to maintain a constant core body temperature:

1) Fitness Level. The improvements in cardiovascular endurance found with training appear to provide additional protection during cold exposure.
2) Skin-Fold Thickness. Subcutaneous fat provides excellent insulation, and a thicker skin fold will provide a greater resistance to heat loss; however, mogul skiers tend to be quite lean and should therefore, be monitored closely.
3) Surface area: mass ratio. The smaller the body the larger the surface area and thus the greater the potential for heat loss. Mogul skiers tend to be smaller individuals at a greater exposure to environmental conduction, convection and radiation.
4) Wind. Air moving rapidly over the skin will significantly increase convective heat loss during cold exposure.
5) Wet Clothing. Water, because of its greater ability to conduct heat compared with air of the same temperature, can promote a much quicker loss of body heat.

The coaching staff and strength and conditioning practitioner should take the following into consideration when preparing athletes for training or competition in cold environments:

1) Proper warm ups should be performed to bring muscle temperatures up and increased blood flow to working muscles prior to racing or training. Tissue temperature should be increased by 3 degrees Celsius prior to training for optimal performance (Young & Behm, 2002).
2) Wearing appropriate clothing is essential. The insulative effects of clothing should be utilized to maintain comfort during training and competition. Clothing should be layered to take advantage of the insulating effect of air trapped between the layers. The first layer, commonly called the base layer, should be made of fabric with moisture wicking properties such as polypropylene. The second layer, or mid layer, should be good insulators such as wool, down or synthetic materials with similar properties. The third layer should be water and wind resistant and can be opened or discarded to provide cooling as the body begins to produce heat. The fourth and final layer, consists of clothing that is worn between competitive or training runs and should be water proof and an excellent insulator. This layer should only be worn at rest and shed during activity (Cappert, 2002).
3) Athletes should be instructed to avoid rapid cooling after exercise cessation. Post exercise hypothermia can develop because heat production has significantly fallen while heat loss remains high. Athletes should add clothing or other insulation or seek a warm environment soon after finishing a competitive or training event (Cappert, 2002).

SECTION #6

DEMANDS OF TRAVEL

Travel Considerations

FIS World Cup level athletes experience frequent transmeridian travel demands. During the 2017-2018 season World Cup athletes traveled a total of 91,631 miles to 10 different countries in a period of 7 months. Many times, athletes will cross 8-12 time zones every 5-10 days for competition. The mode of travel varies and includes: air, rail, bus, or automobile travel. Some ground transportation could be in excess of 5 hours following transmeridian flight. How athletes and coaches manage the frequent travel can be critical to the success of the athlete.

2017-2018 WORLD CUP TRAVEL STATISTICS	
MILES TRAVELED	91,631
TIME ZONES CROSSED	150
TOTAL NUMBER OF FLIGHTS	36
TOTAL NUMBER OF COUNTRIES VISITED	10
TOTAL NUMBER OF CONTINENTS VISITED	4

The unique combination of physiological, psychological, and environmental factors associated with travel may cause detrimental effects on an athlete's ability to recover and perform. Dependent on the direction and length of the travel, these factors may include jet lag, disruption of circadian rhythm, joint stiffness, dehydration, and sleep disruption. Mechanisms of travel fatigue are a result of transitory alterations in human physiology because of rapid air travel across multiple time zones and is commonly referred to as jet lag (Williams, Clarke, Aspe, Cole, & Hughes, 2017).

Jet lag can manifest as sleep disturbances, day-time fatigue, lack of concentration, headaches, irritability, loss of appetite, and gastrointestinal disturbances. Most of the symptoms associated with jet lag mainly occur because of the desynchronization between the body's internal time-keeping system and the external environment (Williams, Clarke, Aspe, Cole, & Hughes, 2017). There are two strategies, as referenced by Dr. Bill Sands (Managing Jet Lag, 2018), that seem to have the greatest amount of merit when assisting the athlete who is coping with transmeridian travel: 1) compete and/or train immediately upon arrival; or 2) compete and/or train after the body has had time to resynchronize with the current time zone. The first, competing immediately upon arrival, is somewhat impractical due to the very nature of air travel. Challenges such as delays, security screenings, and weather make planning for such a strategy impossible.

Therefore, the coach and athlete should focus their energy on acclimating as quickly as possible upon arrival at a new destination.

The coping strategies for such events include:

1) Managing Light Exposure – On arrival, depending on the timing, intensity, and duration, exposure to bright light can advance or delay the circadian phase. Athletes and coaches should time bright light exposure by avoiding bright light before the body temperature nadir and seek bright light after (Williams, Clarke, Aspe, Cole, & Hughes, 2017).
2) Coping with and Avoiding Sleep Deprivation – Sleep deprivation can have negative effects on athletic performance and can occur from both sleep loss during air travel (overnight flights) and jet lag (the need for a circadian advance or delay). To reduce these effects, it is recommended that sleep during travel be maximized. Additionally, naps of less than 30 minutes are not susceptible to “sleep inertia,” the fatigued state experienced upon waking from sleep (Meir, 2002).
3) Nutritional Recommendations – Food and drink requirements should be discussed with athletes prior to departure. During air travel, the dry air circulated in flight cabins can increase the likelihood of dehydration; therefore, athletes should pay special attention to fluid intake. Upon arrival, meals should coincide with the destinations time zone to aid with circadian advances or delays. Athletes should be instructed to avoid caffeine, nicotine and other stimulants. Finally, the use of sleep aids, such as melatonin, L-tryptophan, or valerian root could be beneficial for those who have difficulty coping with sleep disturbances (Meir, 2002).
4) Clothing Choices – Compression garments have been suggested to provide beneficial effects (reduction of blood pooling and venous thromboembolism) while alleviating discomfort and difficulties associated with prolonged sitting in a cramped position during air travel (Sands, Managing Jet Lag, 2018).
5) Exercise – When possible, periods of mobilization should be practiced to promote blood flow and reduce the risk of venous thromboembolism, joint stiffness, and muscle cramps that could result from long periods of inactivity during travel. While awake, athletes should stretch and move about the cabin. Upon arrival, to

benefit from exercise-induced circadian phase shifts, it is recommended to perform exercise early in the morning when body temperature is lowest (Meir, 2002).

6) Behavioral Changes – The athlete and coach are in direct control over many of the factors listed above. Some of the most common behavioral changes include: keeping the cabin windows down, turning off your cabin light until an hour before arrival, ensuring good sleep hygiene (e.g., avoiding caffeine, nicotine, food, and brain stimulating activity), supplementation use (e.g., melatonin), ensuring a comfortable space (e.g., bring the right pillow, slippers, and clothing), timing and dose of exercise, and seating arrangements (Meir, 2002).

7) Individual Considerations – Jet lag effects are influenced by a number of individual differences in people, and range from chronotype, age, fitness level, and adaptability of sleep patterns. Morning-type people who arise early and retire early are less affected by eastward travel, whereas evening-type people who retire late and arise late have less difficulty flying westward. Also, younger athletes (18-25) are less affected by jet lag symptoms as compared to older athletes (25-32). Finally, physically fitter athletes should experience less difficulty with jet lag as they have a higher capacity for stress tolerance (Williams, Clarke, Aspe, Cole, & Hughes, 2017).

8) Mental Attitude – Athletes should adopt a positive mental attitude before getting on the plane. The flight should be seen as a means to an end. Athletes should be encouraged to adopt a passive mindset and remain resistant to distractions that might cause anxiety or tension. At all times, they should keep things in perspective; delays are a part of being in transit (Williams, Clarke, Aspe, Cole, & Hughes, 2017).

SECTION #7

SPORT & SKILL DEMANDS

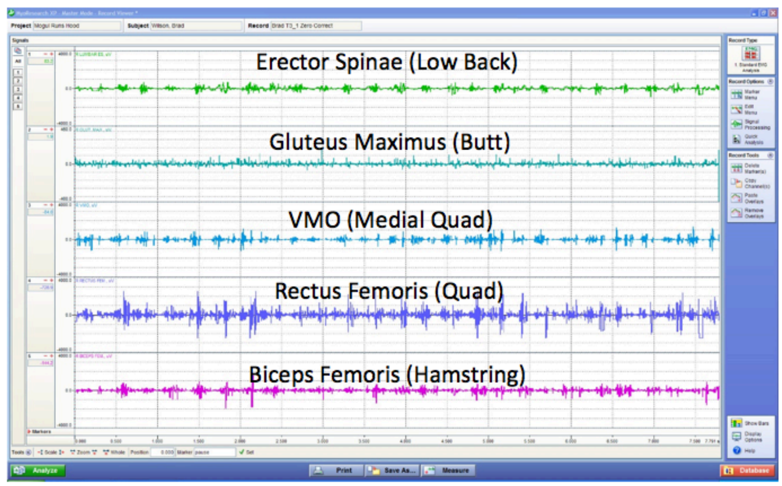
Electromyography

To date, no published data exists on muscle activation patterns of mogul skiers. Electromyography (EMG) is a safe, easy, and non-invasive way to objectively quantify the energy of the muscle. This, in turn, leads to a greater understanding of how the nervous system participates in the orchestration of muscle function.

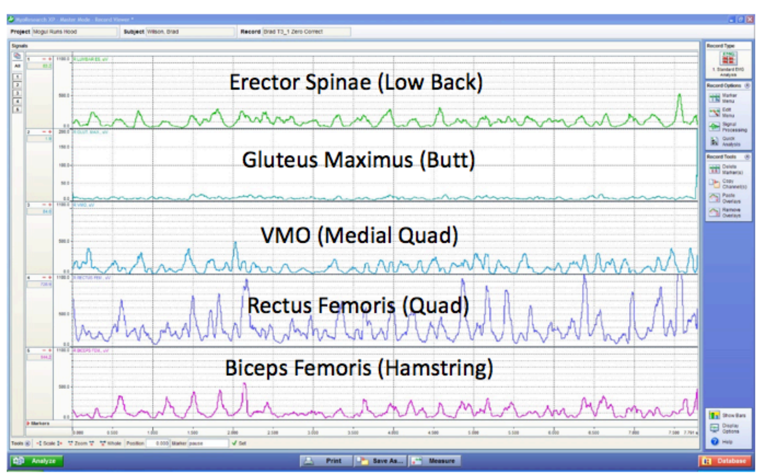
In June 2018, Sands and Bullock conducted a study using EMG on mogul skiers in Mt. Hood, Oregon. In that process, 4 skiers, two males and two females, of distinctly different “style” or technique were selected for the project. The four goals of this project were as follows:

1) Decipher the relative involvement and activation of musculature
2) Determine the dominant motor pattern of the sport
3) Validate a mogul specific test
4) Gauge the effectiveness of certain special exercises to prepare athletes.

The raw data can be seen in the images below.

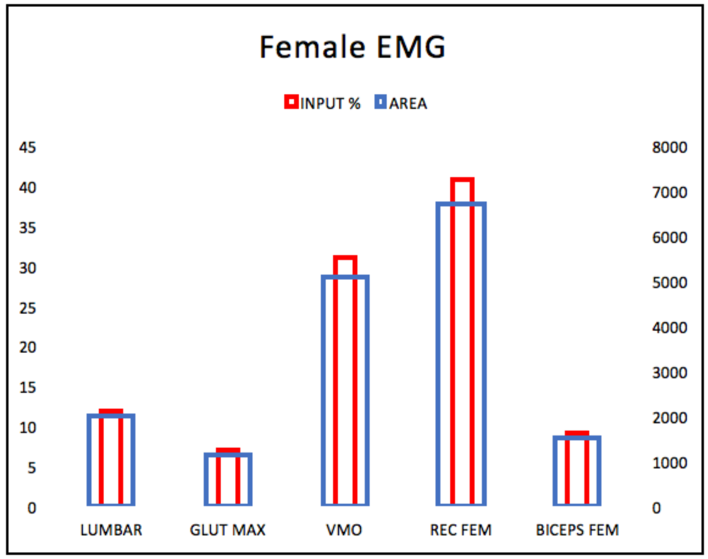


Raw EMG Signals Data



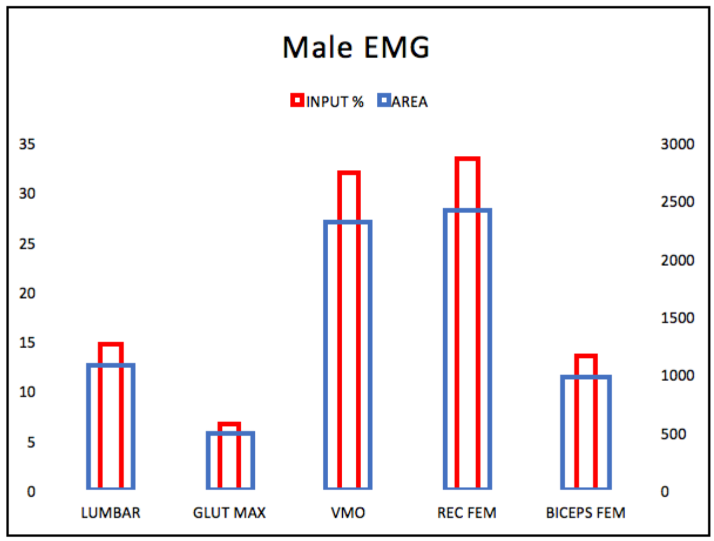
Rectified, Smoothed, and Signal Envelope (Integrated)

Sands and Bullock (2018) measured the activation of five muscles based upon athlete feedback and coach's observation of the sport. The musculature measure included: 1) Erector Spinae (low back), 2) Gluteus Maximus (buttocks), 3) Vastus Medialis Oblique (quadriceps), 4) Rectus Femoris (quadriceps), and 5) Biceps Femoris (hamstring). Results of the EMG indicate a strong similarity between both genders and all ski "styles" or techniques. Dominant musculature includes the quadriceps (VMO and Rectus Femoris) as well as the low back (erector spinae) while the gluteus maximus and biceps femoris activate to stabilize the knee and correct poor or inefficient body position.



The relative input percentage for each of the muscles measured in females is as follows (Sands & Bullock, EMG of Mogul Skiers, 2018):

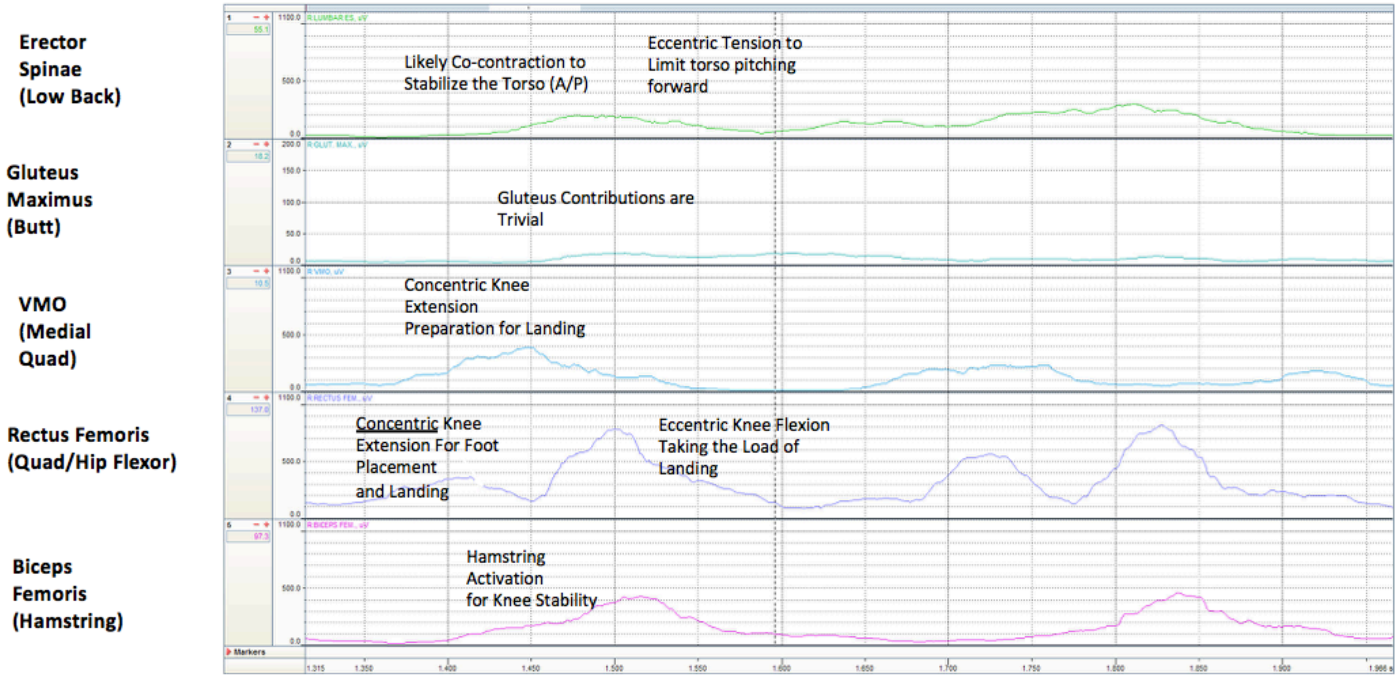
- Erector Spinae: 10-15%
- Glute Max: 5-10%
- VMO: 30-35%
- Rectus Femoris: 40-45%
- Biceps Femoris: 5-10%



The relative input percentage for each of the muscles measured in females is as follows (Sands & Bullock, EMG of Mogul Skiers, 2018):

- Erector Spinae: 15-20%
- Glute Max: 5-10%
- VMO: 30-35%
- Rectus Femoris: 30-35%
- Biceps Femoris: 10-15%

The motor pattern of mogul skiers serves to control the athlete's descent through a series of muscle actions that absorb the impact of the bumps while at the same time repositioning the athlete's feet and maintaining an upright posture of the trunk (Sands & Bullock, 2018). As the skier moves left to right across the page one can see the motor pattern.

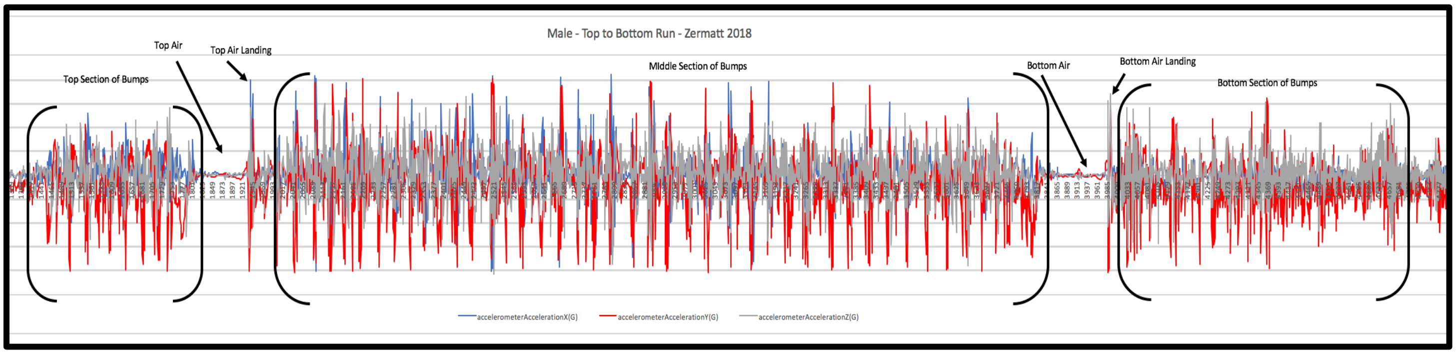


Accelerometry

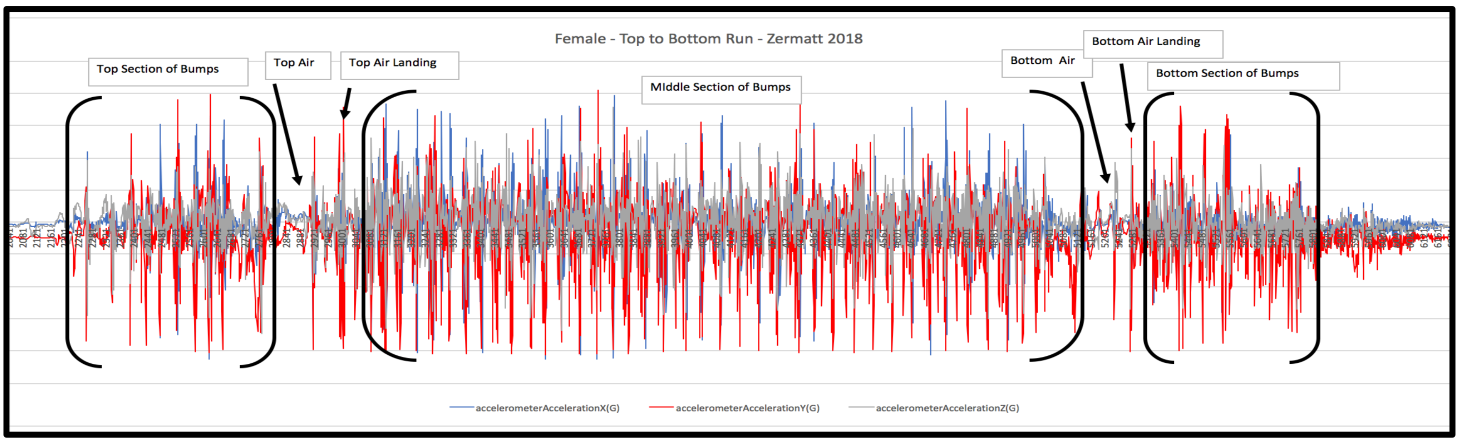
To date, no published data exists on the forces applied to and absorbed by a mogul skier, elite or novice. Unpublished data, collected and analyzed internally by Bullock and Sands, was acquired in October 2018, in Zermatt Switzerland. That data was collected at 100hz, a sample rate which may be at the lower end of useful. However, given the lack of current literature perhaps some training considerations could be drawn.

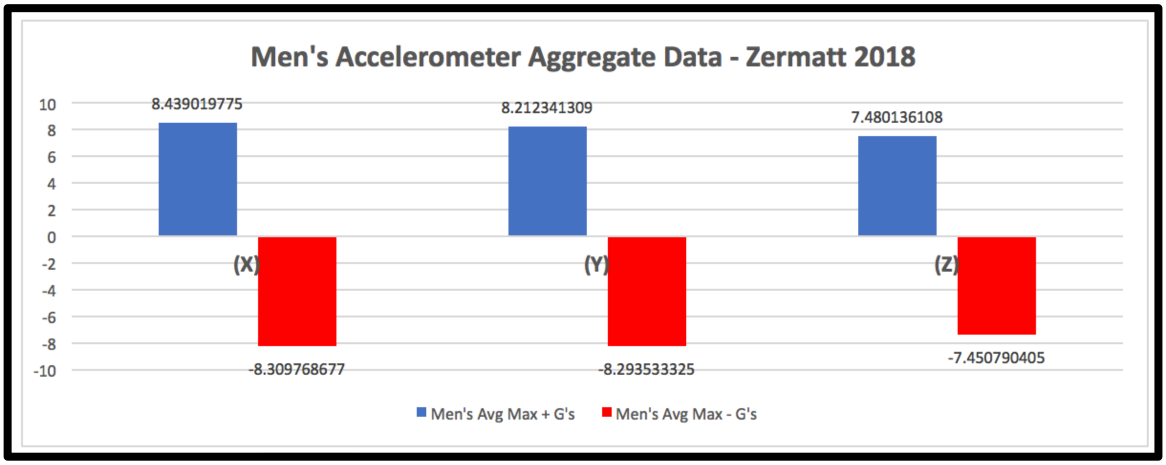
Three women and five men skied a full length, 250-meter course, going from the top to the bottom without stopping. Participants were instructed to ski an aggressive competition run to emulate those conditions as closely as possible.

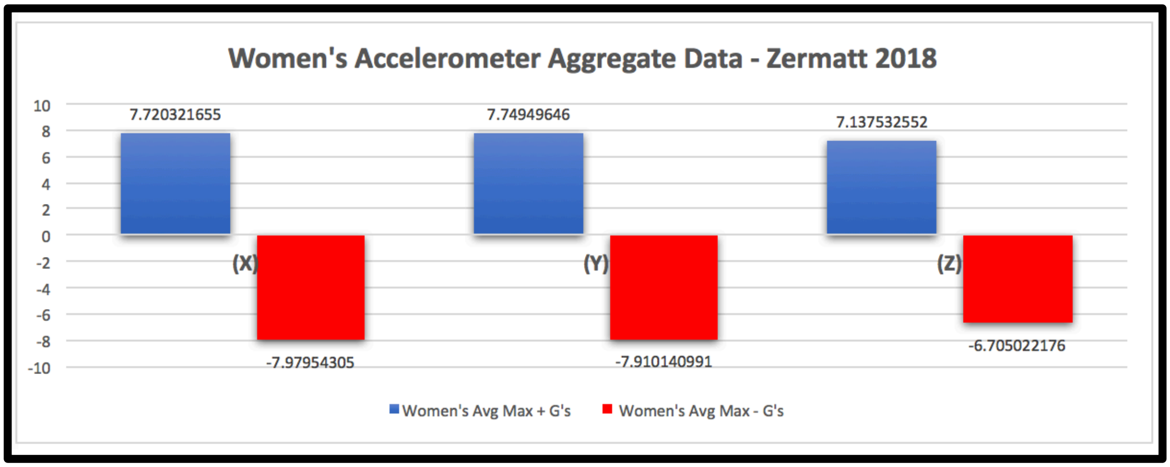
Raw data from a male top to bottom run – Zermatt 2018.

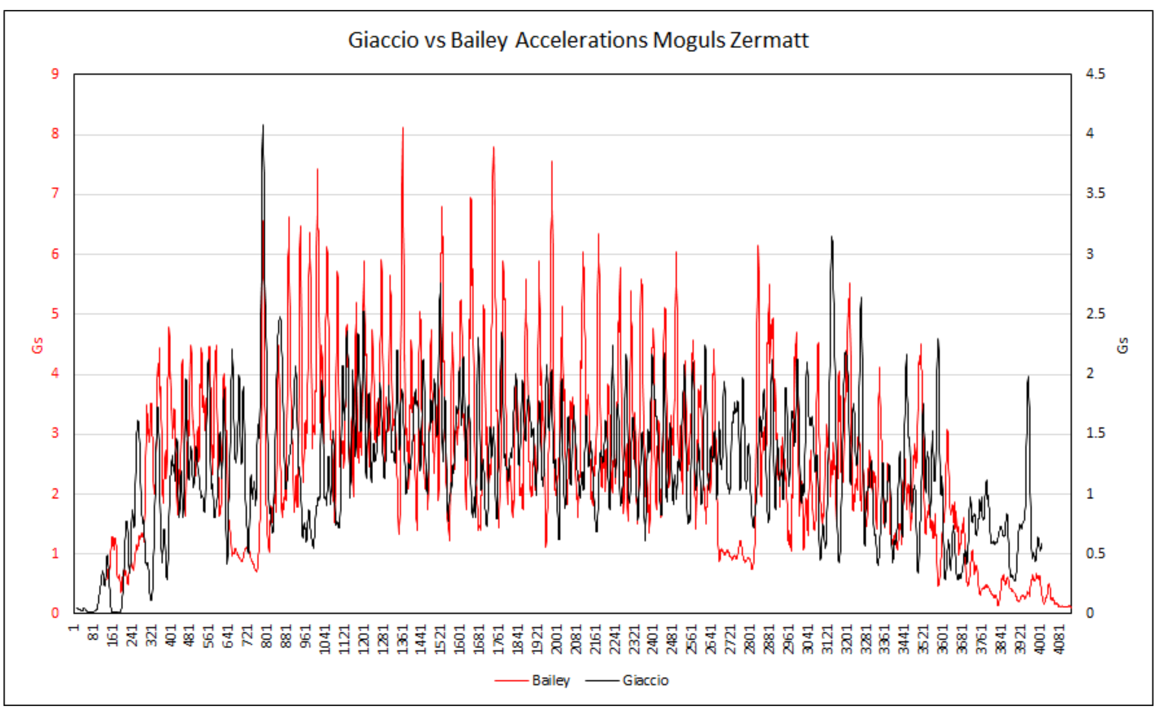


Raw data from a female top to bottom run – Zermatt 2018.









Aggregate data reveal that men experience higher average and peak G-forces than women in all planes of motion with the most dramatic difference in the X-axis as males tend to travel down the hill with much higher speeds than females; 8.44 for males, 7.72 for females (Sands & Bullock, Acclerometry of Mogul Skiers, 2018).

Interestingly, landing forces differed slightly between the sexes: 8.29 for males and 7.91 for females (Sands & Bullock, Acclerometry of Mogul Skiers, 2018).

These data have important considerations for athlete preparation as athletes must be able to absorb significant forces repeatedly for 23-27 seconds or approximately 60-65 contacts as they descend the moguled course.

The final graph at the left presents a male mogul skier (Bailey) and a female mogul skier (Giaccio) on the same course. It is easy to see how each navigates the motor problem. The male (Bailey) appears to attack the course; while the female (Giaccio) appears to float.

Energy Systems

To date, no current literature exists on the physiology of mogul skiers or the quantification of relative energy system contributions for the sport. To quantify energy system contributions a three-pronged approach has been undertaken: 1) the evaluation and application of energy system contribution of 200-m track running events, 2) the evaluation of energy system contribution from a simulated mogul course containing 39 separate 18-inch drops done at maximal speed, and 3) the evaluation of heart rate and blood lactate response from mogul skiing in a full training course in Zermatt, Switzerland.

200 Meter Sprint Running

From a face validity standpoint, World Cup mogul skiing appears to be very like that of a 200-m sprint lasting approximately the same amount of time (20-27s) with both producing a maximal effort from the athlete. For the 200-m, an anaerobic energy system contribution (based on accumulated oxygen deficit) of 28%-72% for males and 33%-67% for females is estimated (21%-79% and 22%-78% based on La/PCr measures; NS from Accumulated Oxygen Deficit estimates) (Duffield, Dawson, & Goodman, 2004).

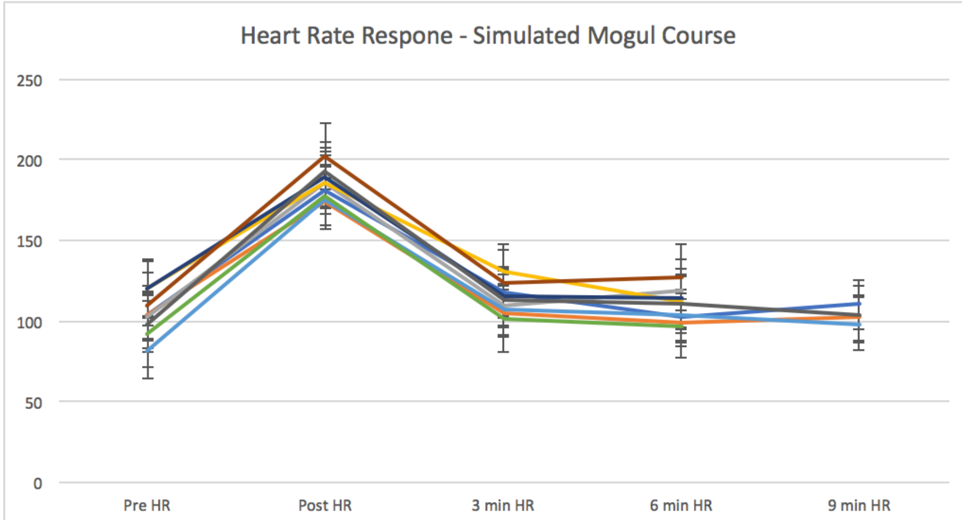
In a study by Hautier et al. (1994) blood lactate concentration was taken within three minutes of race completion in 200-m runners at the Cameroon national championships. The 12-national level male sprinters blood lactate upon completion averaged 10.3mmol·l^{-1}(SD 0.8). The results of this study suggest that at the velocities studied anaerobic glycolysis contributes to at least 55% of the energy expenditure related to sprint running the 200-m (Hautier, et al., 1994). Numerous studies have shown similar results regarding energy system contribution and blood lactate accumulations (see tables at the right).

	AOD		La/PCr	
Event	**% aerobic**	**% anaerobic**	**% aerobic**	**% anaerobic**
100-m Male	**20.6** (±7.9) (13 - 35)	**79.4** (±7.9) (65 – 87)	**8.9** (±3.3) (6 – 14)	**91.1 *** (±3.3) (86 – 94)
Female	**25.0** (±7.4) (17 – 33)	**75.0** (±7.4) (67 – 83)	**10.9** (±5.8) (6 – 19)	**89.1 *** (±5.8) (81 – 94)
200-m Male	**28.4** (±7.9) (17 - 40)	**71.6** (±7.9) (60 – 83)	**20.7** (±8.5) (14 – 35)	**79.3 #** (±8.5) (65 - 86)
Female	**33.2** (±8.0) (26 – 45)	**66.8** (±8.0) (55 – 74)	**22.0** (±7.7) (15 – 28)	**78.0** (±7.7) (72 – 85)

	100-m Male	200-m Male	100-m Female	200-m Female
Race time (s)	11.5 (±0.4)	23.8 * (± 1.1)	13.1 (±0.5)	26.8 # (±1.2)
Peak race $\dot{V}O_2$ (ml·kg^{-1}·min^{-1})	17.85 (±8.53)	32.19 * (±7.31)	13.92 (±7.04)	26.59 (±12.25)
% peak $\dot{V}O_2$	33.0 (±12.9)	56.6 * (±13.2)	31.7 (±18.3)	59.2 (±27.5)
Peak race HR (bpm)	175 (±10)	186 (±11)	189 (±11)	190 (±11)
% HR max	91 (±5)	93 (±4)	99 (±1)	99 (±1)
Peak $[La^-]_b$ (mMol·l^{-1})	9.0 (±1.5)	10.4 (±3.0)	8.7 (±1.7)	10.8 (±2.3)
Race AOD (ml O_2eq·kg^{-1})	17.4 (±4.4)	28.4 (±3.7)	12.4 (±2.9)	22.5 (±3.0)
La/PCr anaerobic total (ml O_2eq·kg^{-1})	45.9 (±5.1)	50.1 (±9.4)	45.2 (±5.2)	52.6 (±7.4)
Total Energy Cost (ml O_2·kg^{-1}·m^{-1})	0.218 (±0.046)	0.198 (±0.012)	0.166 * (±0.035)	0.169 (±0.014)
Speed (m·s^{-1})	8.6 (±0.2)	8.4 (±0.4)	7.7 (±0.3)	7.4 (±0.5)

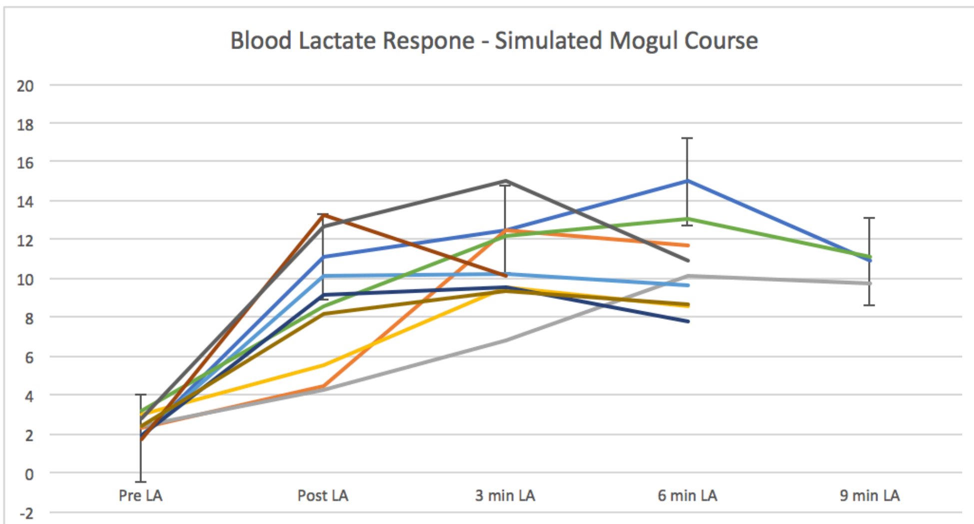
Simulated Mogul Course

In the spring of 2018, Sands and Bullock devised a simulated mogul course that consists of three sections of 13 x 18-inch drop jumps broken up by two sections of 13 x 18-inch box jumps. When performing the test, males wore a weight vest adding 10% of their current bodyweight while females performed the test with no additional weight. The athletes were instructed to "ski" down the course traversing left and right, just as they would on a mogul course, until they reach the bottom. The athlete then jumped rapidly back the top, descended again in the same fashion, jumped one final time to the top, and descended one final time in the same fashion to the bottom. The athlete was timed, heart rate is monitored and recorded and blood lactates were taken pre, post, and every three minutes until peak blood lactate was achieved (Sands & Bullock, Energy System Demands of Mogul Skiers, 2018).



This test has been validated using EMG for both relative muscular input and motor pattern similarities (Sands & Bullock, EMG of Mogul Skiers, 2018).

Time to completion of the test for females averages 33.19 seconds and for males 31.55 seconds; making the test slightly longer than a competitive mogul run (Sands & Bullock, Energy System Demands of Mogul Skiers, 2018).



Heart rate climbs quickly throughout the test peaking upon completion at an average of 91% of max in men and 94% of max in women (Sands & Bullock, Energy System Demands of Mogul Skiers, 2018).

Blood lactate concentration typically peaks between one and three minutes upon completion of the test with an average peak of 11.80mmol·l^{-1} among all participants (Sands & Bullock, Energy System Demands of Mogul Skiers, 2018).

Women appear to have a higher average peak blood lactate than men at 11.98mmol·l^{-1} and 11.73mmol·l^{-1} respectively (Sands & Bullock, Energy System Demands of Mogul Skiers, 2018).

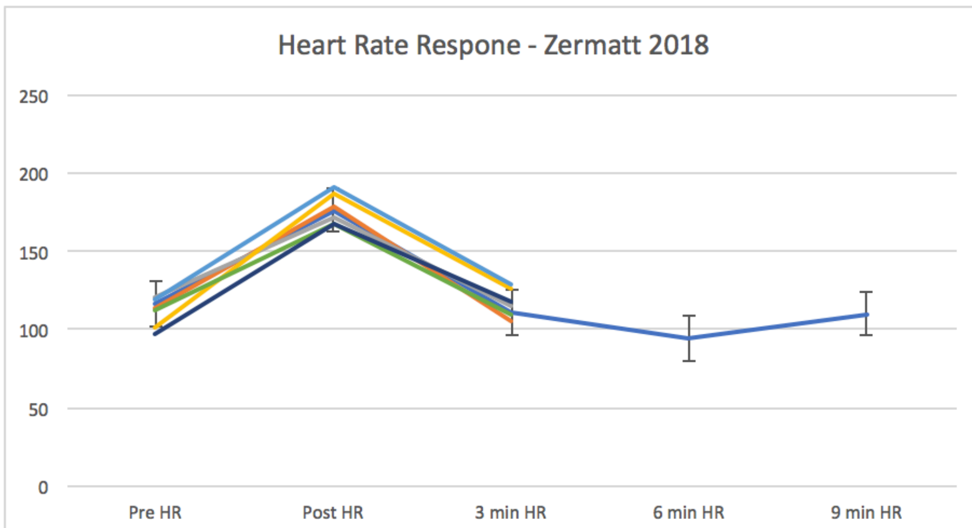
The graphs above are from one test session (5 males, 5 females) conducted on May 30, 2018; the second such test in the pilot study.

Mogul Course Training

In the fall of 2018, athletes at training camp in Zermatt, Switzerland replicated the testing protocol used on the simulated mogul course to first, quantify the energy system contribution of a training run and second, further validate the use of the simulated mogul course as a tool for preparing athletes for the sport of mogul skiing. A third goal of the camp, was to evaluate the energy system contribution regarding a single full day of training.

Just as in the simulated mogul course, the athlete was timed, heart rate was monitored and recorded and blood lactate was taken pre, post (30-90s upon completion of the run based on coaching), and every three minutes until peak blood lactate accumulation is achieved (Sands & Bullock, Energy System Demands of Mogul Skiers, 2018).

Time to completion of a single training run for females averages 27.84 seconds and for males 28.82 seconds; making these training runs slightly shorter than the simulated mogul course. All timing for this project was completed using the Free Lap timing system (Sands & Bullock, Energy System Demands of Mogul Skiers, 2018).

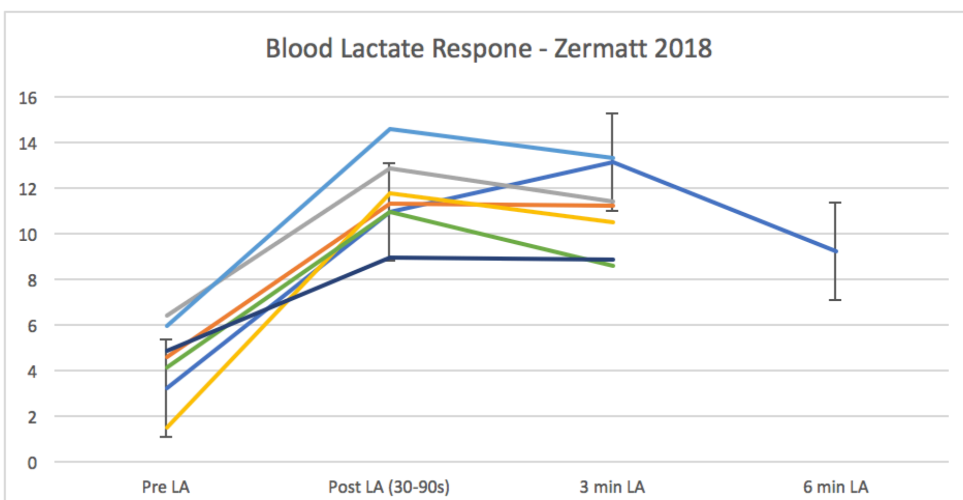


Heart rate climbs quickly throughout the run peaking at an average of 89% of max upon completion among all participants (Sands & Bullock, Energy System Demands of Mogul Skiers, 2018).

Blood lactate concentrations typically peaks between one and three minutes upon completion of the test with an average peak of 11.90mmol·l^{-1} among all participants (Sands & Bullock, Energy System Demands of Mogul Skiers, 2018). It is important to note that blood lactate was not taken immediately post run in all cases, but rather between 0 and 90 seconds upon completion of the run as a matter of practicality.

In total 7 athletes were tested in Zermatt, 2018; two females and five males. Thus, a small sample size may be a limiting factor to this information. Additionally, the Zermatt mogul course is located at 12,400 feet in the Swiss Alps making elevation a second consideration for interpretation of these results.

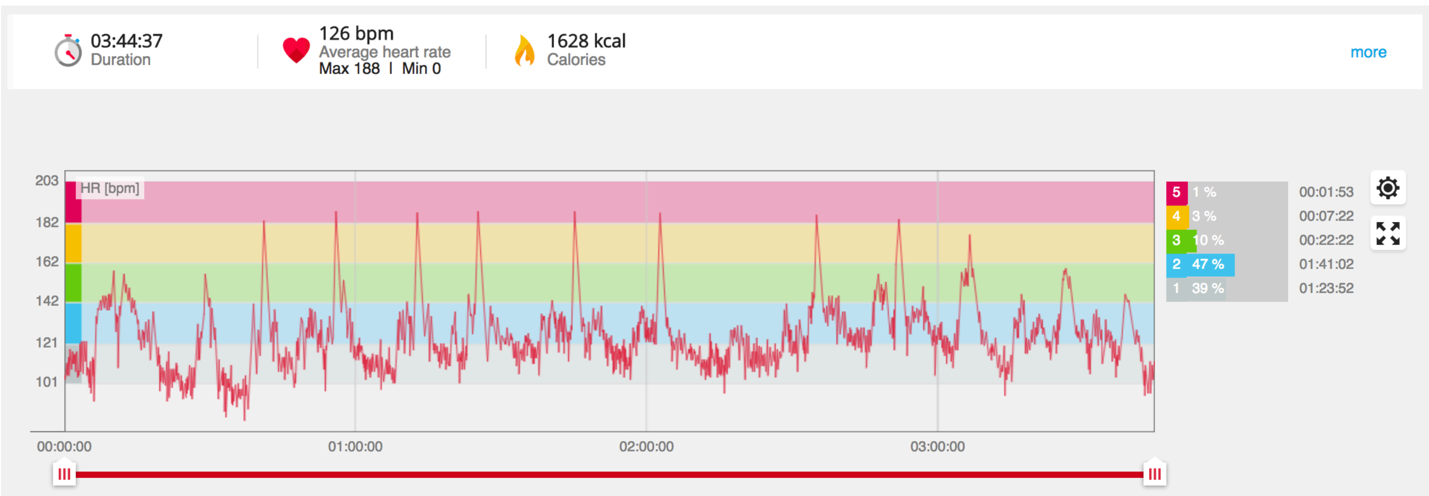
See above for heart rate and blood lactate graphs of a single run, with a recovery period in Zermatt 2018.



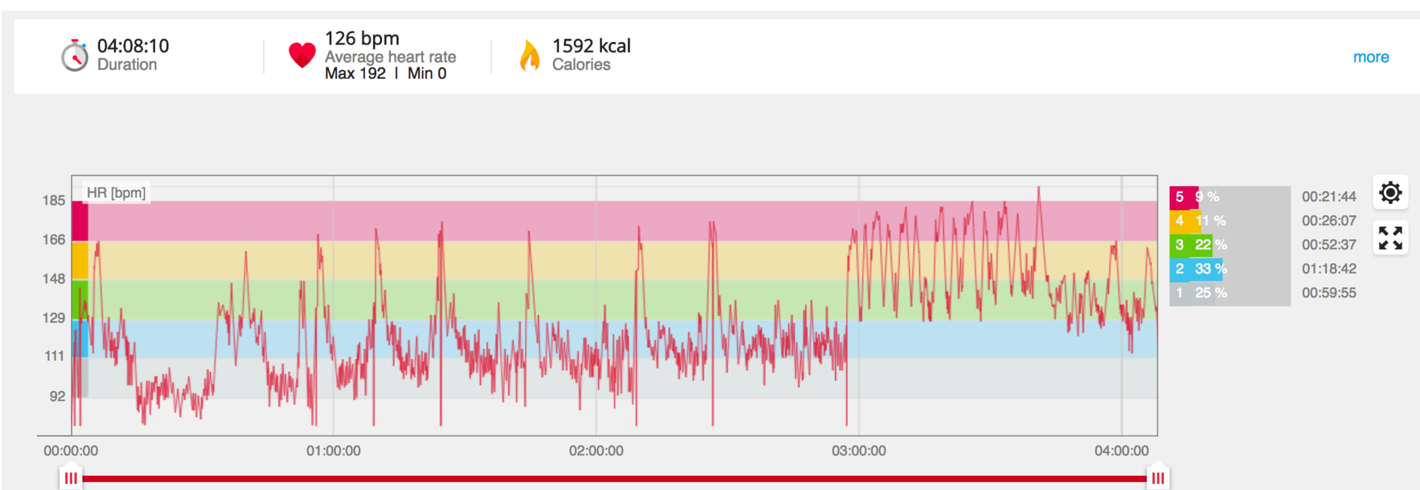
It is important to note that while the sport of mogul skiing, in and of itself is very anaerobic (see above), however, the nature a singular training session appears stress the athlete across multiple energy systems. This stress induced, therefore, is highly variable depending upon the content of that training session. It is very important for the coaching staff and performance personnel to understand the load (both acutely and chronically) that is being placed on the individual athletes. In short, while one training session is being conducted the stress on each individual athlete is likely very different.

Heart Rate Data

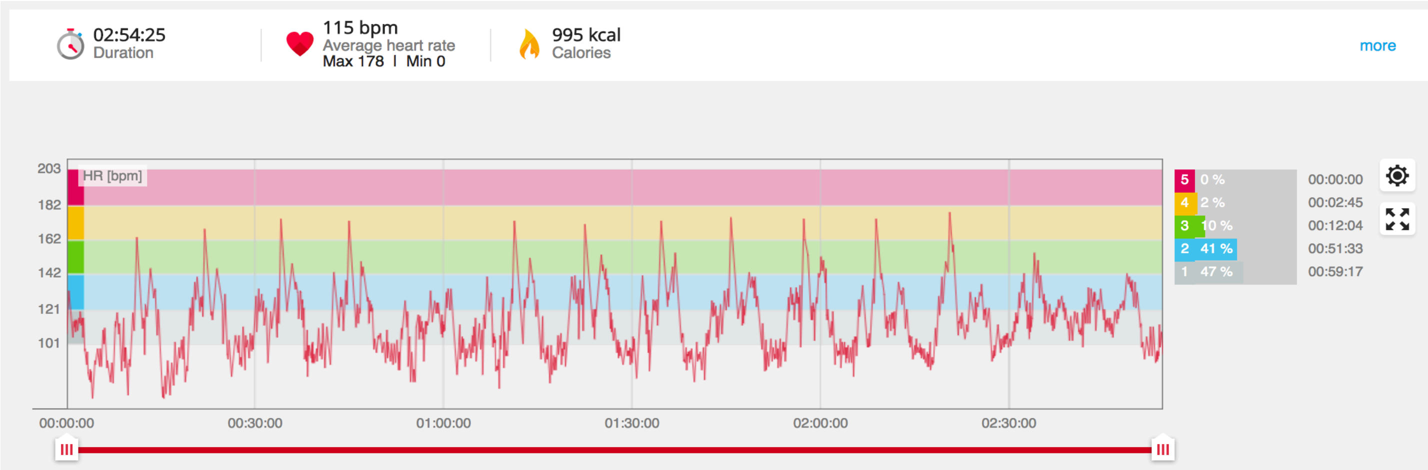
Below are some sample training sessions taken in Zermatt, Switzerland, Wolf Creek, Colorado, Mt. Hood, Oregon, and the Utah Olympic Park water ramps using Polar H10 heart rate monitors. Bullock (Energy System Demands of Mogul Skiers, 2018) has captioned the training sessions for content.



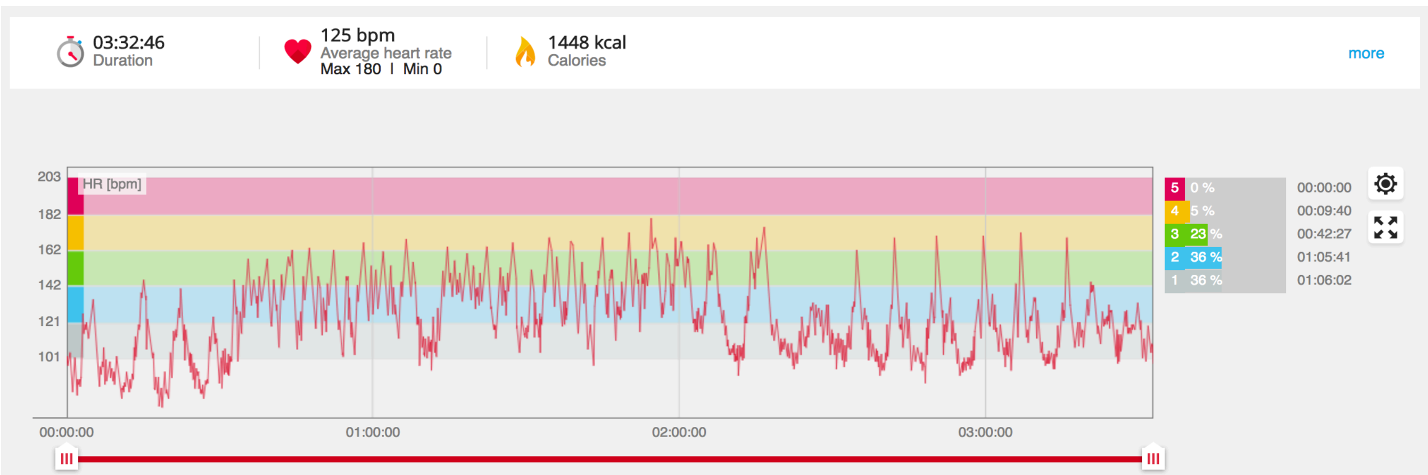
One training session conducted in Zermatt 2018. This graph is very typical of a mogul skiers training sessions where the emphasis is on skiing the course. **Content of this session:** Top to bottom training with sectioned skiing at the end of the training session.



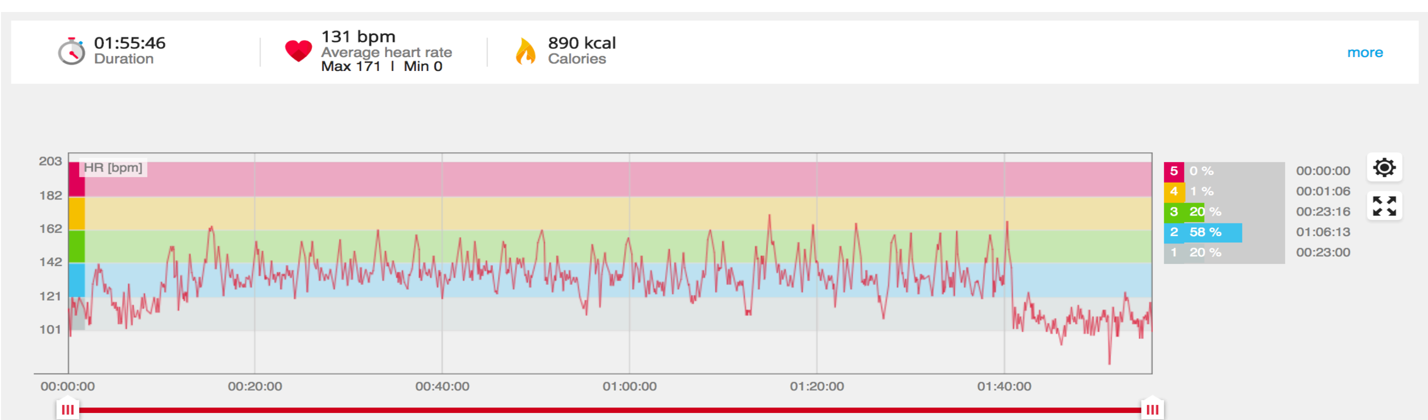
One training session conducted in Zermatt 2018. This graph is very typical of a mogul skiers training sessions with an emphasis on jumping. **Content of this session:** Top to bottom training with jump training (hiking) at the end of the training



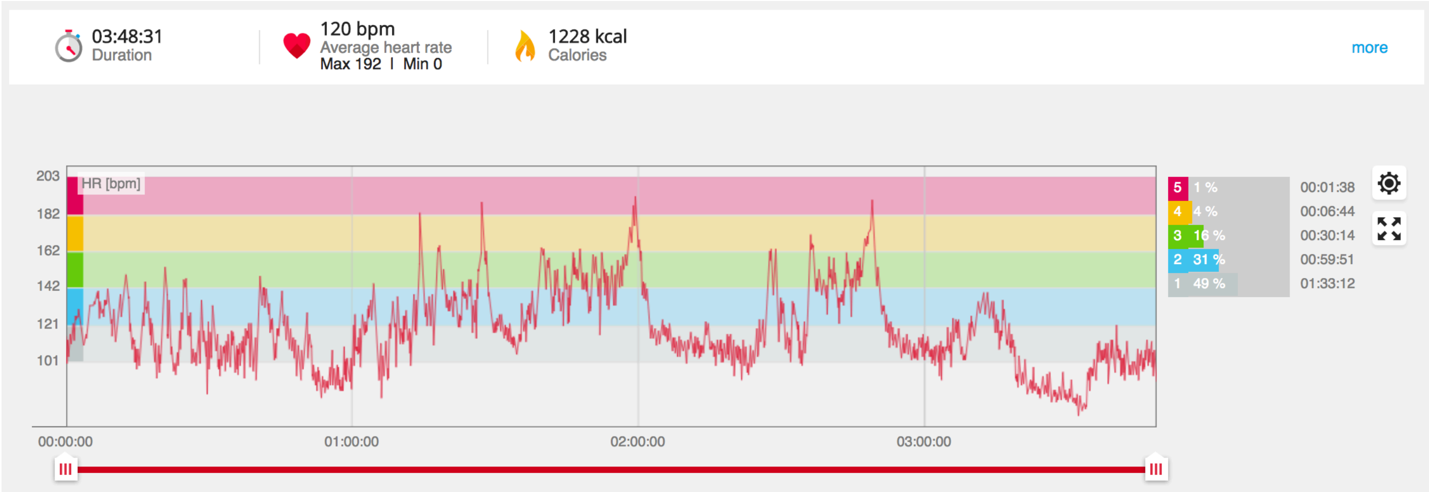
One training session conducted in Wolf Creek, CO 2018. This graph represents training of a partial course (150m). **Content of this session:** Partial course training. 150m course with one jump and longer free skiing out run.



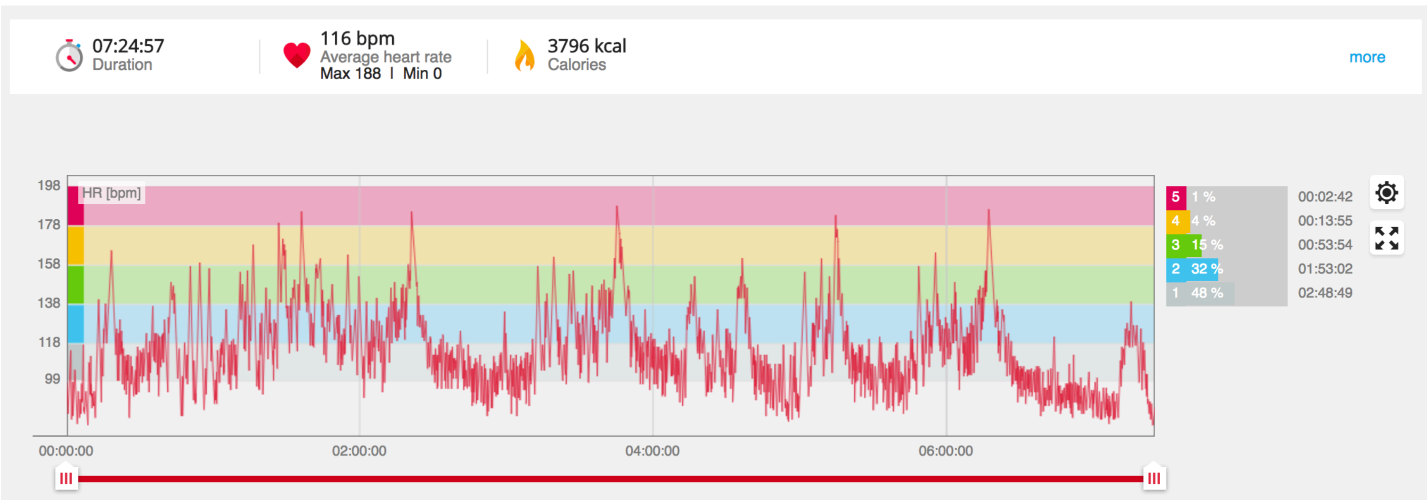
One training session conducted in Mt. Hood, OR 2018. This graph represents training on a constructed on-snow jump site. **Content of this session:** On-snow jump training. Athletes jump and hike approx. 30m back to the top.



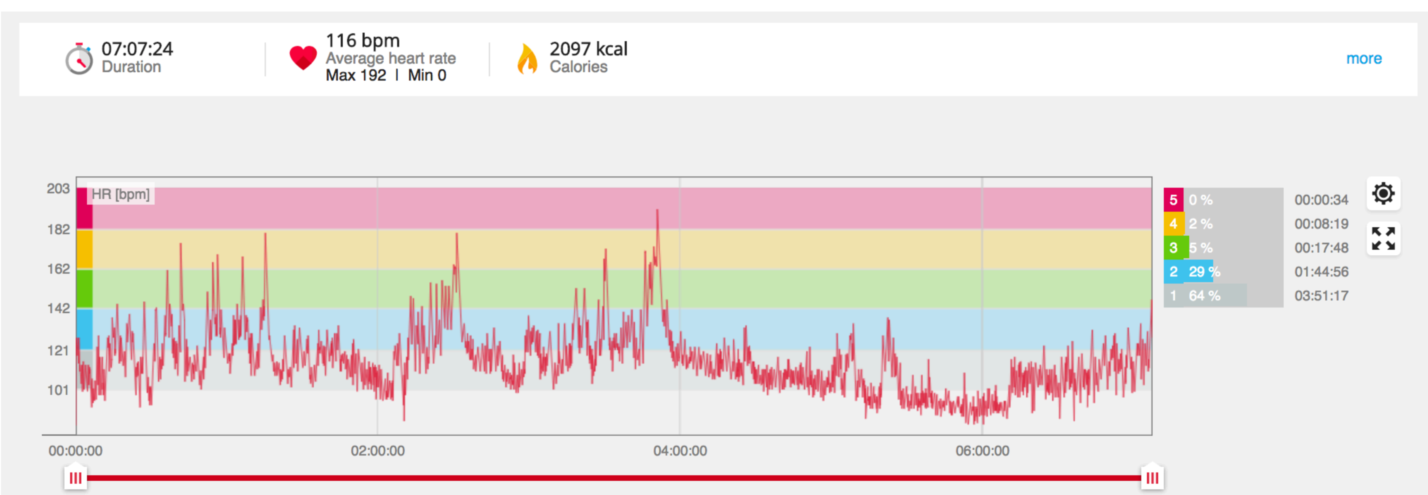
One training session conducted in Park City, UT 2018. This graph represents training at the water ramps at Utah Olympic Park. **Content of this session:** Water ramp jump training. Athletes jump and hike several flights of stairs back to the top.



Competition Day - Single Moguls in Ruka, Finland, December 2018. Women's session #1 of a split session. This graph shows two competition runs - Q1/Q2. **Content of this session:** Moguls training, qualification #1, and qualification #2.



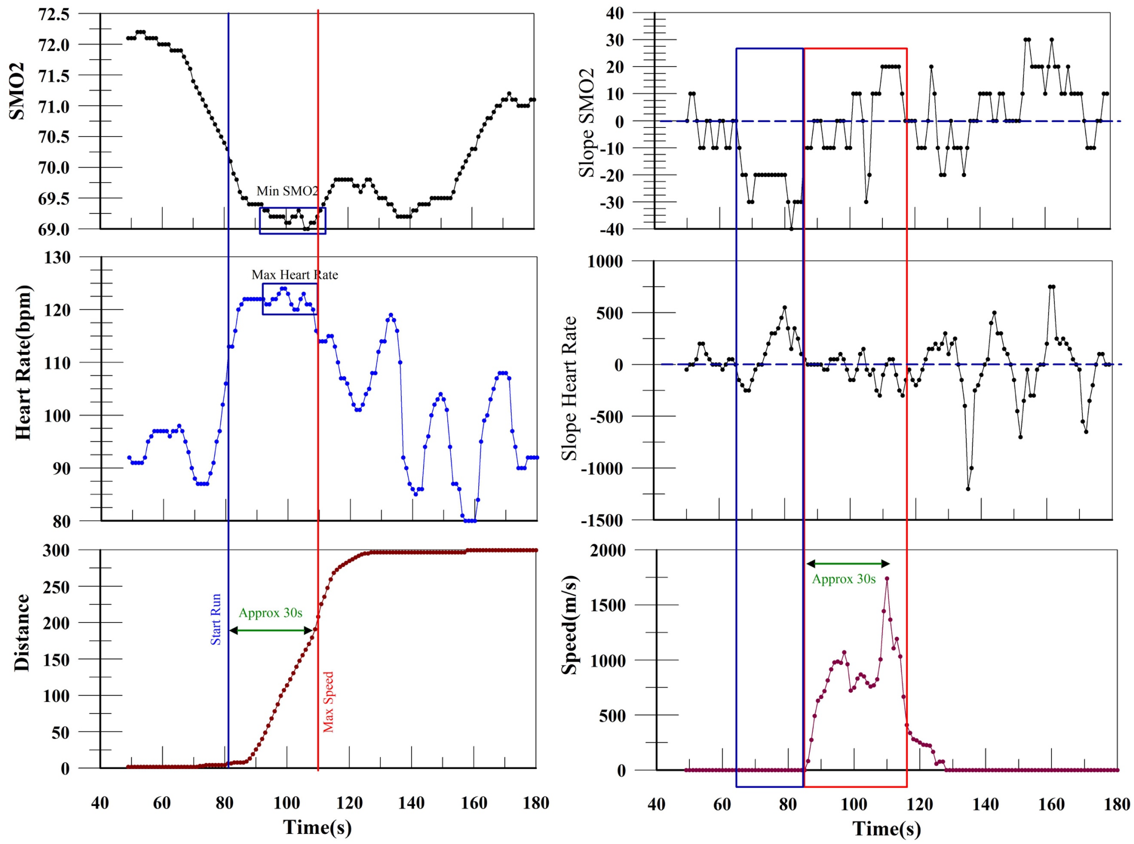
Competition Day - Single Moguls in Ruka, Finland, December 2018. Men's session, a singular long session with multiple runs. This graph shows three competition runs – Q1, Q2, F1. **Content of this session:** Moguls training, qualification #1, qualification #2, finals training, finals #1.



Competition Day - Dual Moguls in Thaiwoo, China, December 2018. This graph shows training and two competition runs. **Content of this session:** Moguls training, Round of 16, round of 8.

Muscle Oxygen Saturation

The Humon near-infrared spectroscopy device is used to measure hemoglobin saturation in muscle tissue. This technology has only recently been acquired by US Ski and Snowboard and prior to its current application has never been used on freestyle mogul skiers. In December of 2018 Bullock and Sands acquired and analyzed data from a Thaiwoo, China official training session that featured top to bottom competition simulated mogul runs. Bullock (Energy System Demands of Mogul Skiers, 2018) has annotated the training sessions for content.

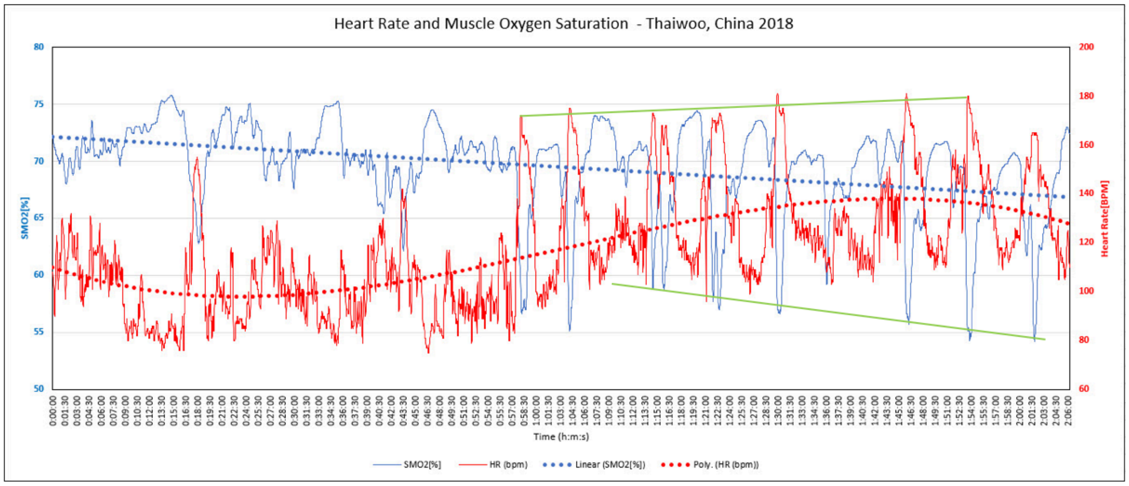


The 2018 data revealed muscle oxygen saturation (SMO2) reaches its minima at about the same time as the max heart rate. This is probably obvious and expected. These two systems will likely covary as one is involved in supplying the other.

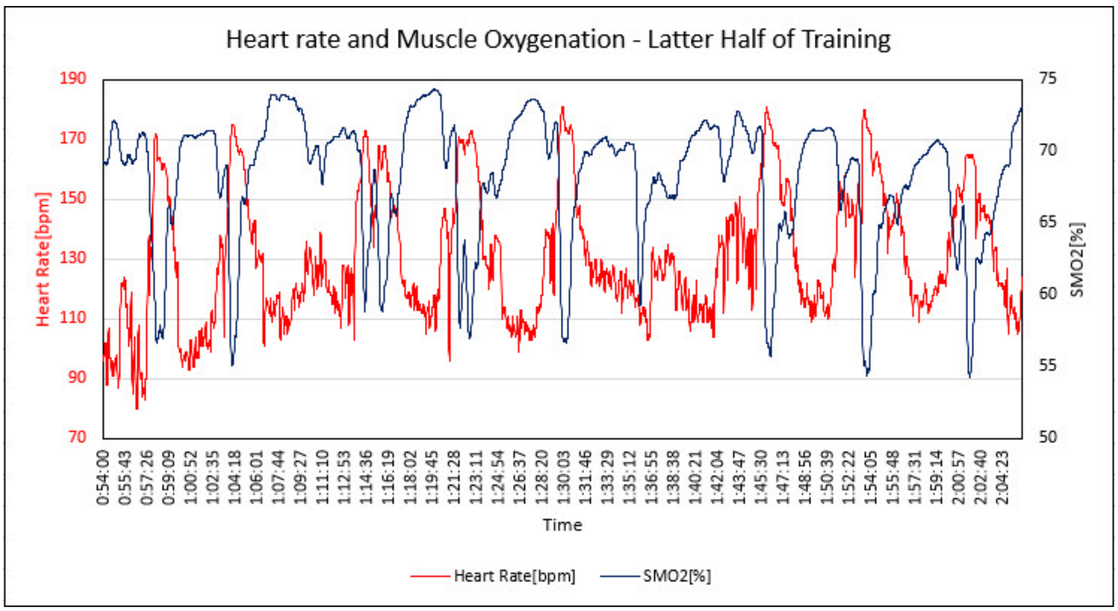
The three graphs on the right are descriptive in terms of muscle oxygenation, heart rate, and distance covered. The three on the right are "rate-oriented" graphs, rate of change of muscle oxygenation, heart rate, and position (i.e., speed). The left-side graphs show that the metabolic response of the athlete occurred in two phases. There is a rapid drop in muscle oxygenation immediately prior to the race likely due to the state of arousal, followed by a slower decline in rate (right side) and magnitude (left side). The SMO2 continues to decline during the race but more slowly (indicated by the negative portion of the top-right graph). As the oxygen saturation is declining immediately prior to the actual race, note that heart rate increases dramatically (middle-right graph) to compensate. The most rapid decline in the rate of change of oxygen saturation occurs about mid-race. This is roughly coincident with a further decline of heart rate. As such, both systems attempting to oxygenate the muscle are doing rather poorly. This may be related to muscle tension now partially occluding blood supply to the thigh. As the race nears the end, the muscle oxygenation is increasing in rate, but not in magnitude. At this moment, heart rate is decreasing in both rate and magnitude. This may indicate a maximum capability of oxygen saturation at this point. These parameters may be useful to test in future training tasks and durations.

The above information shows that the Humon device should probably be included during training for short-term stamina such that the exercise task(s) mimic these results. From a physical preparation standpoint, lactate buffering and training with blood flow restriction (BFR) may also be merited for these athletes; especially in those with an advanced training age.

The two graphs below display data collected in Thaiwoo, China in December 2018, the top graph is an entire training session and the bottom graph is the second half of a training session. Note that the second half of the training session looks quite different and as such, the data from 54 minutes to the end has been extracted.

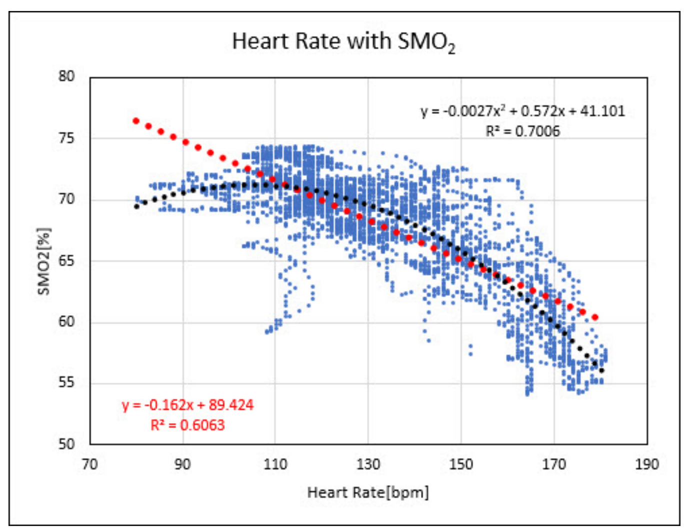


Of importance are the peaks of heart rate and the minimums of SMO2. As training proceeds their inverse relationship is portrayed quire clearly. As the athlete begins top to bottom training heart rate response eclipses 180 bpm while SMO2 declines below 55%. As the athletes training duration extends his heart rate response peaks and his SMO2 levels decline steadily with each run (green lines). This may be a sign of increasing fatigue, or perhaps trying harder.



Finally, given the close correspondence between the heart rate and SMO2 one might predict one from the other. Unfortunately, that does not appear to be the case.

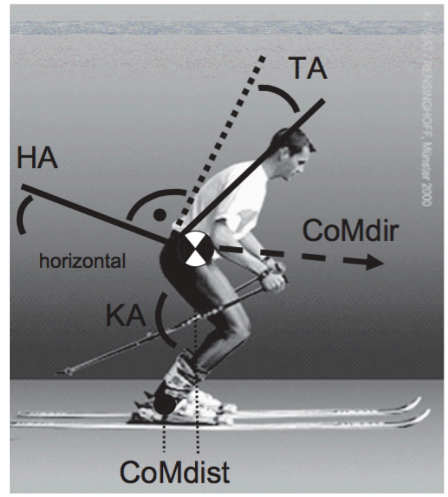
The relationship between heart rate and SMO2 is best described as a non-linear relationship. This is shown by the black dotted line (graph at right). Heart rate can only explain about 70% of the variation in SMO2 (Sands & Bullock, Muscle Oxygen Saturation in Mogul Skiers, 2018).



Biomechanics

To date there are just two studies on the biomechanics of mogul skiing. In one such study, Kurpers and McAlpine (2009), examined the effects of using a force measurement device on riding technique in mogul skiing. That study was completed on professional mogul skiers (either instructors or competitors) and analyzed knee angle, side and forward lean of the trunk and hip, and path of the body's center of mass. To accommodate the for the difficulties of filming, this study was done on an indoor mogul course. Unfortunately, the other study, by Ikegami et al., was published in 1994 before the advent of man-made mogul courses with standardized specs and jumps; however, some conclusions may still be drawn. More research in this area is needed.

Kurpers and McAlpine assessed body motion over three runs using 3D video analysis. A four-camera high-speed video system (Simi Motion with Basler A602f cameras) mounted to the walls of the building collected video footage at 101 Hz. Knee angles ranged from 77° to 156° degrees. The average knee flexion on the inside legs was greater than on the outside legs. For the hips and upper body, several parameters were calculated, which may be used to characterize forward leaning of the skier. Lateral flexion of the upper trunk against the hip segment (SideFlex) on average shows a flexion away from the turning direction as it is expected in parallel turns. The front flexion of the upper trunk against the hip segment was similar at the start and end of the swing, i.e., on top of the moguls and straighter in the dip between moguls indicated by a smaller angle. Forward inclination of the hip is less negative when going through the dip, indicating a more upright posture according to a combined knee and hip extension in this phase. The sideways movement of the hip shows almost exclusively negative values, indicating a slight left tilt compared with the standing trial (Kurpiers & McAlpine, 2009).



Above: Graphical illustration of kinematic parameters investigated (KA=Knee Angle, TA=forward lean of the trunk, HA=forward tilt of the hip in a world coordinate system, CoMdir=path of the body's center of mass, CoMdist=horizontal distance of CoM and a point halfway between both ankle joint centers.

Parameters	Normal		Initial		Familiarised	
	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.
InsideKneeFlexionMax [deg]	93	5	101	12	91	9
InsideKneeExtensionMax [deg]	135	10	133	11	131	11
OutsideKneeFlexionMax [deg]	96	9	106	8	94	9
OutsideKneeExtensionMax [deg]	137	11	142	10	135	6
SideFlexHipMin [deg]	−20	6	−19	4	−18	4
SideFlexHipMax [deg]	−3	8	−1	6	1	7
FrontFlexHipSt [deg]	29	11	30	8	28	10
FrontFlexHipF [deg]	29	7	25	11	22	10
FrontFlexHipMin [deg]	4	10	1	8	2	9
FrontTiltTrunkSt [deg]	−10	4	−11	4	−11	4
FrontTiltTrunkF [deg]	−12	3	−16	5	−13	4
FrontTiltTrunkMax. [deg]	−5	2	−6	3	−6	3
CoM_foot [mm]	323	59	280	77	261	71

Above: Mean Values and Standard Deviations of Kinematic Parameters for the Three Relevant Runs (F = at Finish, Min = Minimum, Max = Maximum, CoM = Centre of Mass, CoM foot = Horizontal Distance Between CoM and a Point Half Way Between Both Ankle Joint Centres)

When interpreting the above information one must proceed with caution as certain limitations do exist. First, the sample size used in the study was relatively small (8 individuals). Second, the study was completed on an indoor mogul course in an attempt to keep the height of the moguls consistent; a condition that rarely, if ever, takes place in the field. Third, participant only skied over 4 bumps which may explain the slightly asymmetric sideways orientation of the hip segment. On a continuous mogul run, it would be expected that hip orientation would be symmetric (Kurpiers & McAlpine, 2009).

The fundamentals of the ski turn have remained relatively unchanged over time. The parallel turn is initiated by a kinetic chain to provide sufficient force to complete a turn (Arndt, 1992). As described by Arndt (1992) the initiation of the turn begin at the hip, continues through the knee joint to the ankles and feet whereby force is applied to the edges of the ski. The turning force in advanced skiing is provided by the rotation of the lower limbs against the relatively stable, larger mass of the upper body. A larger friction force is developed by edging the skis into the snow to overcome centrifugal force and gravity forces (Arndt, 1992).

Arndt (1992) gave a two-dimensional kinematic description of the movements necessary for a skier to maintain balance despite the rapid changes in ground reaction force from the snow surface experienced when skiing down the fall line over two uniform bums constructed on a gentle slope. In the study a comparison was made between skilled and intermediate skiers that showed accelerations in the lower body and the range of joint motion at the knees and hip of the skilled skier were large, whereas the accelerations and trajectory of the upper body were relatively stable.

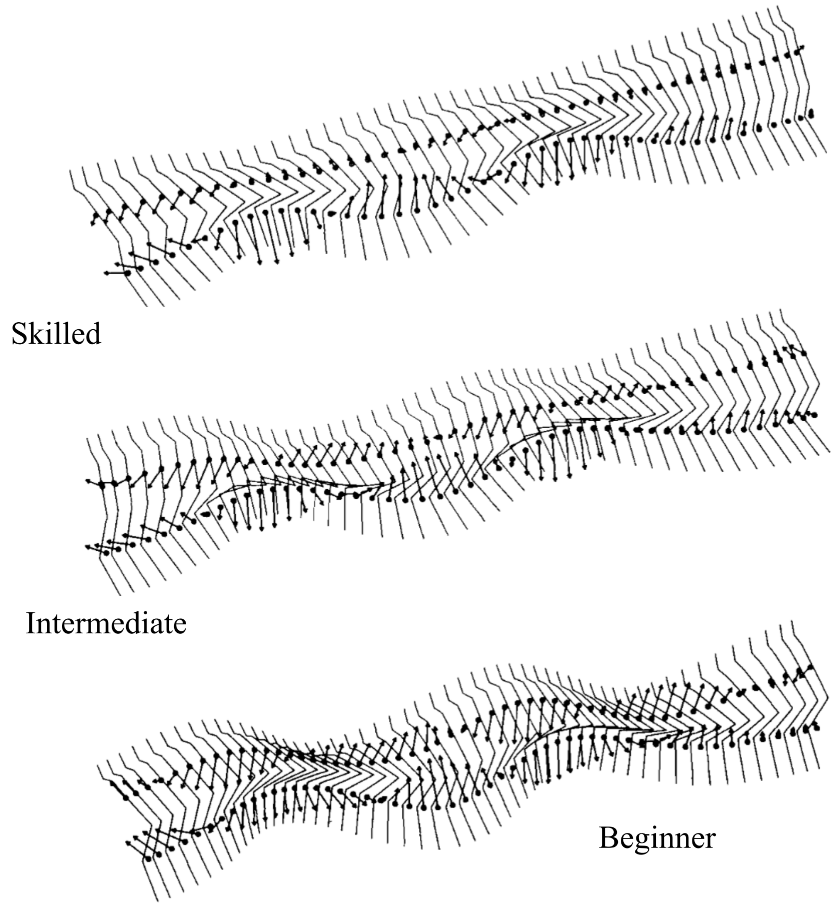


Image Above: A stick depiction of a mogul skier's body showing the vertical displacement of the head, shoulders, trunk and hips. Top=skilled, Middle=Intermediate, Bottom=Beginner

The skilled skiers actively extended the hip and knee immediately after skiing over the bump. This prevented the skier's body from falling down the far side of the mogul and from receiving the impact force of the snow surface after the bump (Arndt, 1992). This observation that was validated by Sands and Bullock (2018) in a study using EMG on mogul skiers.

SECTION #8

MANAGING THE TRAINING PROCESS

United States Ski and Snowboard National Team athletes can undergo several test batteries at the Center of Excellence (COE) in Park City, UT. These tests are generally not required, but many athletes participate in such testing approximately two or more times per year. Athlete participation ranges from none, to sporadic and inconsistent, to complete and consistent.

The test batteries are administered by the High-Performance Department via the Athlete Development personnel. The data from these tests were entered into five databases consisting of Excel™ spreadsheets housed on the US Ski and Snowboard COE servers. These data were entered manually by the testers with varying levels of vigilance and accuracy (Sands, The Quantified Mogul Skier, 2017).

The fundamental question from this report was: Do the tests administered by the COE personnel discriminate the competitive caliber of national team mogul skiers?

To test this question, Sands (The Quantified Mogul Skier, 2017) hypothesized that the tests and test batteries did not discriminate between athlete groups (null) and that the alternative hypothesis was that the tests and test batteries did discriminate.

The groups were defined as Non-Olympic Games and World Ski Championships (Non) or Olympic Games or World Ski Championships athletes (OlyWSC). Group membership was based on whether the athlete competed at World Cup level at some time during the six years of the collected data or remained below the World Cup level for the six years. The group data were obtained from querying the FIS performance database.

Initial assessment of the athletes showed a difference between the groups in age for all tests. Thus, all comparative analyses involved the Analysis of Covariance (ANCOVA) with age at the time of the test as the covariate. The use of a covariate allows the data to be adjusted based on the covariate, this denotes that the analysis is carried out by statistically equating all the athletes in age.

Data of statistical significance is indicated by bolding and shading, $p<0.05$.

Anthropometric Data

Group Statistics

	Group	Mean	Std. Deviation	N
Test Age	**Non**	**21.93**	**3.49**	**19**
	OlyWSC	**23.99**	**2.64**	**45**
Height (cm)	Non	174.33	5.84	19
	OlyWSC	175.46	4.51	45
Mass (kg)	**Non**	**68.27**	**5.78**	**19**
	OlyWSC	**74.05**	**3.28**	**45**
Subscapular (mm)	Non	8.19	2.00	19
	OlyWSC	8.83	1.72	45
Triceps (mm)	Non	7.07	1.96	19
	OlyWSC	6.16	1.00	45
Biceps (mm)	**Non**	**3.58**	**.73**	**19**
	OlyWSC	**3.18**	**.50**	**45**
Iliac Crest (mm)	Non	11.57	4.77	18
	OlyWSC	10.10	3.21	41
Supraspinale (mm)	Non	7.51	3.63	19
	OlyWSC	6.57	2.06	45
Abdominal (mm)	Non	11.68	5.00	19
	OlyWSC	11.53	3.88	45
Thigh (mm)	**Non**	**11.10**	**5.87**	**19**
	OlyWSC	**7.71**	**1.26**	**45**
Calf (skinfold, mm)	Non	6.39	4.06	19
	OlyWSC	5.12	.82	45
Upper Arm Relaxed Girth (cm)	**Non**	**30.05**	**2.47**	**19**
	OlyWSC	**31.32**	**1.77**	**45**
Upper Arm Flexed Girth (cm)	**Non**	**32.44**	**2.46**	**19**
	OlyWSC	**33.85**	**1.66**	**45**
Waist Girth (cm)	**Non**	**75.41**	**4.66**	**19**
	OlyWSC	**79.24**	**2.98**	**45**
Hips Girth (cm)	**Non**	**93.63**	**3.67**	**19**
	OlyWSC	**95.86**	**2.41**	**45**
Mid-Thigh-R Girth (cm)	**Non**	**51.53**	**4.69**	**19**
	OlyWSC	**54.57**	**2.75**	**45**
Mid-Thigh-L Girth (cm)	**Non**	**51.62**	**4.90**	**19**
	OlyWSC	**53.96**	**2.86**	**45**
Calf Girth (cm)	Non	33.66	8.06	19
	OlyWSC	35.45	1.28	45
Humerus Condylar Breadth (cm)	Non	6.96	.41	14
	OlyWSC	7.18	.36	36
Femur Condylar Breadth (cm)	**Non**	**9.30**	**.42**	**14**
	OlyWSC	**9.60**	**.14**	**36**
Sum 7 Skinfolds (mm)	Non	55.52	21.03	19
	OlyWSC	49.10	7.78	45
Sum 4 Skinfolds (mm)	Non	40.82	17.21	19
	OlyWSC	34.60	7.36	45
Percent Fat (4 Skinfolds)	Non	16.03	4.52	19
	OlyWSC	15.48	2.18	45
Endomorphy Score	Non	2.20	.78	19
	OlyWSC	2.08	.39	45
Mesomorphy Score	Non	1.00	5.57	19
	OlyWSC	2.47	4.77	45
Ectomorphy Score	**Non**	**2.70**	**.87**	**19**
	OlyWSC	**2.04**	**.82**	**45**

Initial Descriptive Statistics - Males

Initial Descriptive Statistics - Males
Independent t-test

Statistical significance is indicated by bolding, $p < 0.05$.

Group Statistics

	Group	Mean	Std. Deviation	N
Test Age	**Non**	**21.61**	**1.71**	**12**
	OlyWSC	**23.61**	**3.62**	**73**
Height (cm)	Non	163.71	3.34	12
	OlyWSC	165.57	5.05	73
Mass (kg)	Non	60.73	3.96	12
	OlyWSC	59.90	5.26	73
Subscapular (mm)	Non	13.58	4.12	12
	OlyWSC	14.00	2.84	73
Triceps (mm)	Non	10.56	2.73	12
	OlyWSC	9.69	2.32	73
Biceps (mm)	Non	5.91	2.05	12
	OlyWSC	5.34	1.91	73
Iliac Crest (mm)	Non	15.79	6.08	9
	OlyWSC	15.01	3.58	63
Supraspinale (mm)	Non	9.03	2.67	12
	OlyWSC	9.58	2.91	73
Abdominal (mm)	Non	16.48	7.67	12
	OlyWSC	14.45	4.34	73
Calf (skinfold, mm)	**Non**	**20.16**	**6.56**	**12**
	OlyWSC	**20.74**	**4.38**	**73**
Thigh (mm)	Non	11.43	2.78	12
	OlyWSC	12.48	3.73	73
Upper Arm Relaxed Girth (cm)	Non	27.42	2.41	12
	OlyWSC	27.31	1.16	73
Upper Arm Flexed Girth (cm)	Non	29.01	2.39	12
	OlyWSC	28.70	.90	73
Waist Girth (cm)	Non	68.14	4.55	12
	OlyWSC	67.40	2.96	73
Hips Girth (cm)	Non	93.99	5.00	12
	OlyWSC	94.15	3.90	73
Mid-Thigh-R Girth (cm)	Non	51.12	2.61	12
	OlyWSC	50.69	3.43	73
Mid-Thigh-L Girth (cm)	Non	51.10	2.67	12
	OlyWSC	50.69	3.50	73
Calf Girth (cm)	Non	34.15	.59	12
	OlyWSC	33.47	1.78	73
Humerus Condylar Breadth (cm)	Non	6.19	.34	12
	OlyWSC	6.20	.22	63
Femur Condylar Breadth (cm)	Non	8.95	.19	12
	OlyWSC	8.74	.36	63
Sum 7 Skinfolds (mm)	Non	87.14	23.95	12
	OlyWSC	86.29	15.12	73
Sum 4 Skinfolds (mm)	Non	59.03	23.38	12
	OlyWSC	57.83	10.11	73
Percent Fat (4 Skinfolds)	Non	19.16	5.78	12
	OlyWSC	18.94	2.51	73
Endomorphy Score	Non	3.40	.93	12
	OlyWSC	3.42	.62	73
Mesomorphy Score	**Non**	**3.96**	**.65**	**12**
	OlyWSC	**2.02**	**3.53**	**73**
Ectomorphy Score	**Non**	**1.94**	**.58**	**12**
	OlyWSC	**2.43**	**.53**	**73**

Initial Descriptive Statistics - Females

Initial Descriptive Statistics - Females
Independent t-test

Statistical significance is indicated by bolding, $p < 0.05$.

Height

Age-Adjusted Standing Height ANCOVA – **Males**

Tests of Between-Subjects Effects

Dependent Variable: Height (cm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	4.214	1	4.214	.171	.681	.003	.069
OlyampWSC	10.931	1	10.931	.443	.508	.007	.100
Error	1505.888	61	24.687				
Total	1964328.340	64					
Corrected Total	1527.340	63					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Standing Height (cm) - **Males**

Dependent Variable: Height (cm)

Group	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Non	174.456[a]	1.182	172.092	176.819
OlyWSC	175.408[a]	.752	173.903	176.912

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.38.

Age-Adjusted Standing Height ANCOVA – **Females**

Tests of Between-Subjects Effects

Dependent Variable: Height (cm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	58.754	1	58.754	2.536	.115	.030	.350
Group	54.782	1	54.782	2.364	.128	.028	.330
Error	1900.081	82	23.172				
Total	2324806.790	85					
Corrected Total	1994.652	84					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Standing Height (cm) - **Females**

Dependent Variable: Height (cm)

Group	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Non	163.288[a]	1.414	160.474	166.102
OlyWSC	165.642[a]	.565	164.518	166.766

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.33.

Body Mass

Age-Adjusted Body Mass ANCOVA – **Males**

Tests of Between-Subjects Effects

Dependent Variable: Mass (kg)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	**137.007**	**1**	**137.007**	**8.911**	**.004**	**.127**	**.836**
Group	**270.290**	**1**	**270.290**	**17.580**	**.000**	**.224**	**.985**
Error	937.886	61	15.375				
Total	336386.380	64					
Corrected Total	1521.624	63					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Body Mass (kg) - **Males**

Dependent Variable: Mass (kg)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	69.006[a]	.933	67.141	70.872
OlyWSC	73.740[a]	.594	72.552	74.927

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.38.

Age-Adjusted Body Mass ANCOVA – **Females**

Tests of Between-Subjects Effects

Dependent Variable: Mass (kg)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	30.958	1	30.958	1.189	.279	.014	.190
Group	13.937	1	13.937	.535	.467	.006	.112
Error	2135.639	82	26.044				
Total	308365.760	85					
Corrected Total	2173.730	84					

b. Computed using alpha = .05

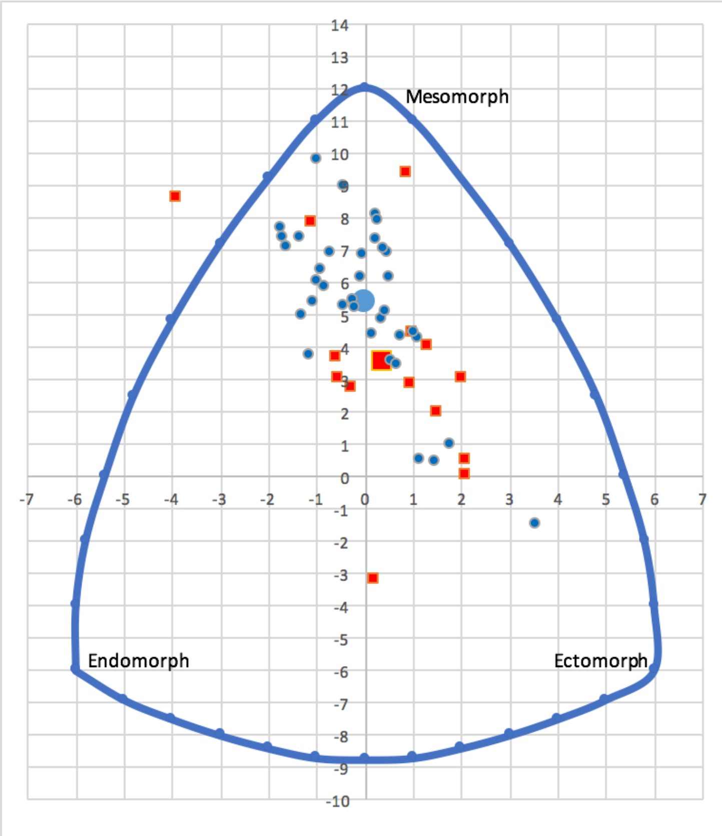
Age-Adjusted Descriptive Statistics Body Mass (kg) - **Females**

Dependent Variable: Mass (kg)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	61.038[a]	1.500	58.055	64.021
OlyWSC	59.851[a]	.599	58.659	61.043

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.33.

Body Type

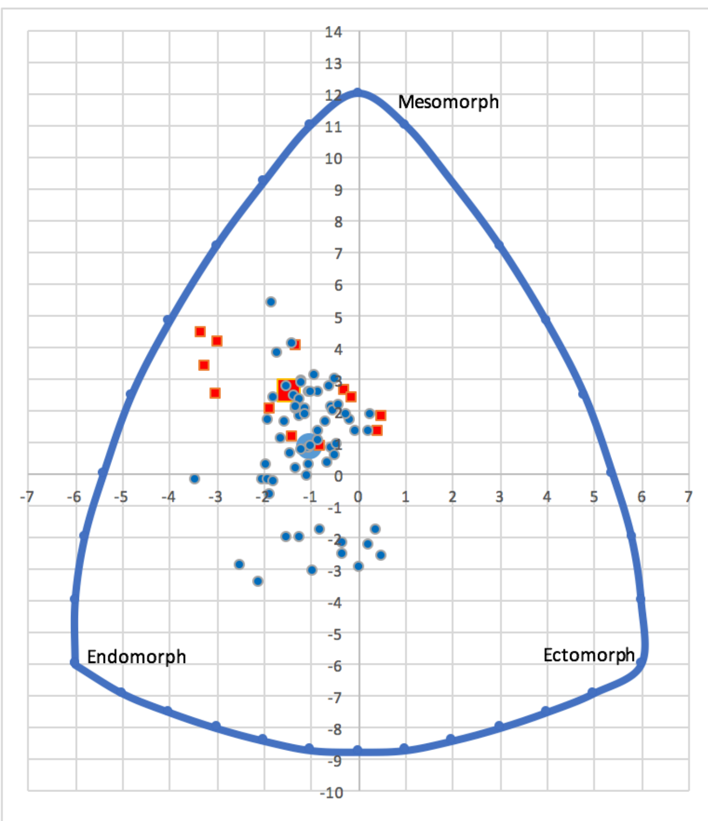


Somatograph.

Male Moguls Skiers.

Red Squares = Non

Blue Circles = OlyWSC



Somatograph.

Female Moguls Skiers.

Red Squares = Non

Blue Circles = OlyWSC

Sum of Seven & Percent Fat

Age-Adjusted Sum Seven Skinfolds ANCOVA – **Males**

Tests of Between-Subjects Effects

Dependent Variable: Sum 7 Skinfolds (mm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
TestAge	.057	1	.057	.000	.986	.000	.000	.050
Group	500.430	1	500.430	2.874	.095	.045	2.874	.386
Error	10620.024	61	174.099					
Total	177700.883	64						
Corrected Total	11170.576	63						

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Sum Seven Skinfolds (mm) – **Males**

Dependent Variable: Sum 7 Skinfolds (mm)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	55.539[a]	3.139	49.261	61.816
OlyWSC	49.098[a]	1.998	45.103	53.093

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.38.

Age-Adjusted Sum Seven Skinfolds ANCOVA – **Females**

Tests of Between-Subjects Effects

Dependent Variable: Sum 7 Skinfolds (mm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	940.355	1	940.355	3.532	.064	.041	.459
Group	12.003	1	12.003	.045	.832	.001	.055
Error	21834.061	82	266.269				
Total	657407.240	85					
Corrected Total	22781.956	84					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Sum Seven Skinfolds (mm) – **Females**

Dependent Variable: Sum 7 Skinfolds (mm)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	85.461[a]	4.795	75.923	94.999
OlyWSC	86.563[a]	1.915	82.752	90.373

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.33.

Age-Adjusted Sum Percent Fat ANCOVA – **Males**

Tests of Between-Subjects Effects

Dependent Variable: Percent Fat (4 Skinfolds)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	9.927	1	9.927	1.068	.305	.017	.174
Group	8.458	1	8.458	.910	.344	.015	.156
Error	566.866	61	9.293				
Total	16244.053	64					
Corrected Total	580.906	63					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Percent Fat – **Males**

Dependent Variable: Percent Fat (4 Skinfolds)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	16.233[a]	.725	14.783	17.683
OlyWSC	15.395[a]	.462	14.472	16.319

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.38.

Age-Adjusted Sum Percent Fat ANCOVA – **Females**

Tests of Between-Subjects Effects

Dependent Variable: Percent Fat (4 Skinfolds)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	23.032	1	23.032	2.366	.128	.028	.330
Group	.086	1	.086	.009	.925	.000	.051
Error	798.379	82	9.736				
Total	31420.451	85					
Corrected Total	821.878	84					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Percent Fat – **Females**

Dependent Variable: Percent Fat (4 Skinfolds)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	18.893[a]	.917	17.069	20.717
OlyWSC	18.986[a]	.366	18.258	19.715

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.33.

Physical Capacities

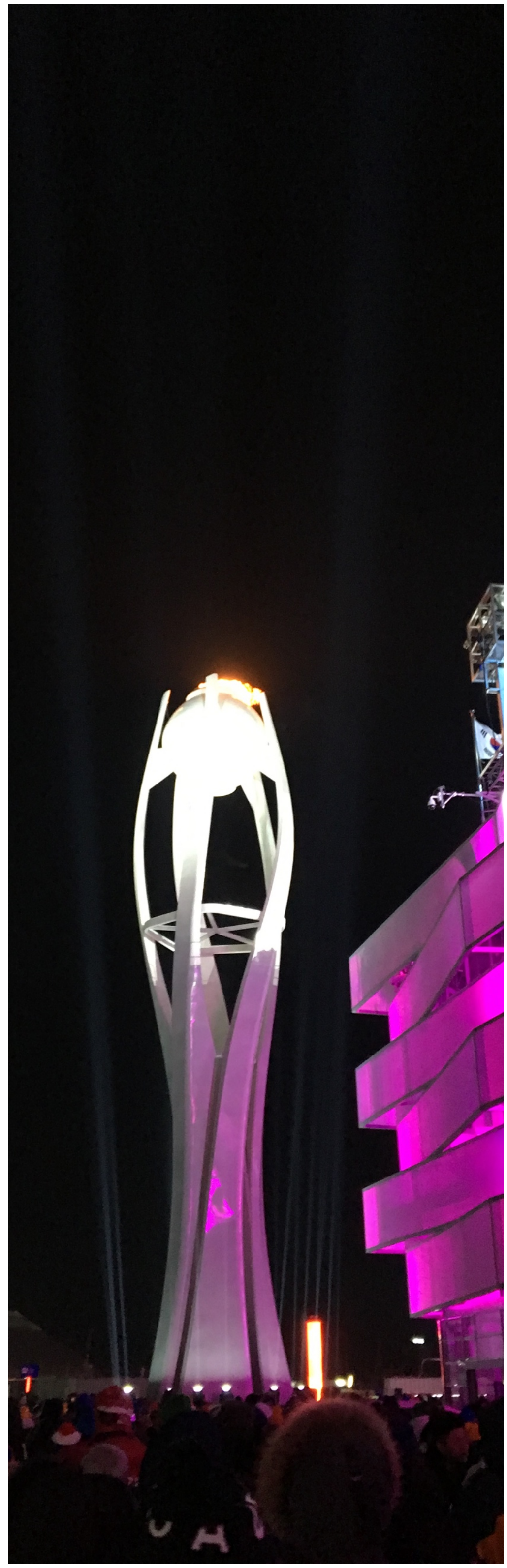
Group Statistics

	Group	Mean	Std. Deviation	N
Test Age	Non	21.81	2.98	39
	OlyWSC	24.31	2.65	62
Body Mass (kg)	Non	67.32	4.08	39
	OlyWSC	74.15	3.84	62
Iso Squat Force (N)	Non	1880.76	186.51	39
	OlyWSC	2213.72	228.55	52
Iso Squat Force (kgf)	Non	191.72	19.01	39
	OlyWSC	225.66	23.30	52
Scaled Iso Squat (kg)	Non	2.85	.20	39
	OlyWSC	3.04	.22	52
SJ Height (cm)	Non	43.73	5.28	35
	OlyWSC	48.62	5.26	54
SJ Force (N)	Non	1613.73	122.87	35
	OlyWSC	1721.59	151.48	53
SJ Power (W)	Non	2594.21	392.72	35
	OlyWSC	3066.78	357.70	52
SJ Scaled Power (W/kg)	Non	38.52	5.99	35
	OlyWSC	41.37	3.94	52
SJ Velocity (m/s)	Non	2.47	.20	35
	OlyWSC	2.66	.19	54
CMJ Height (cm)	Non	51.63	5.16	38
	OlyWSC	55.17	6.01	58
CMJ Force (N)	Non	1661.37	217.83	38
	OlyWSC	2026.16	290.27	58
CMJ Power (W)	Non	3005.24	460.04	38
	OlyWSC	3459.39	411.44	58
CMJ Scaled Power (W/kg)	Non	44.78	7.31	38
	OlyWSC	46.55	4.35	58
CMJ Velocity (m/s)	Non	2.74	.20	38
	OlyWSC	2.86	.24	58

Initial Descriptive Statistics - Males

Initial Descriptive Statistics - Males

Statistical significance is indicated by bolding, $p < 0.05$.



Group Statistics

	Group	Mean	Std. Deviation	N
Test Age	**Non**	**21.00**	**2.57**	**33**
	OlyWSC	**23.48**	**3.67**	**92**
Body Mass (kg)	Non	61.62	4.76	33
	OlyWSC	60.01	4.98	91
Iso Squat Force (N)	Non	1504.55	195.53	31
	OlyWSC	1455.90	211.73	85
Iso Squat Force (kgf)	Non	153.37	19.93	31
	OlyWSC	148.41	21.58	85
Scaled Iso Squat (kg)	Non	2.48	.27	31
	OlyWSC	2.48	.34	85
SJ Height (cm)	Non	34.13	4.33	28
	OlyWSC	32.72	4.68	70
SJ Force (N)	Non	1352.57	195.82	28
	OlyWSC	1298.65	110.06	68
SJ Power (W)	**Non**	**2077.95**	**371.18**	**28**
	OlyWSC	**1899.70**	**371.45**	**68**
SJ Scaled Power (W/kg)	Non	33.62	5.62	28
	OlyWSC	31.77	5.39	68
SJ Velocity (m/s)	**Non**	**2.21**	**.21**	**28**
	OlyWSC	**2.08**	**.19**	**69**
CMJ Height (cm)	**Non**	**38.42**	**4.10**	**25**
	OlyWSC	**35.53**	**6.49**	**81**
CMJ Force (N)	Non	1476.39	183.00	31
	OlyWSC	1434.73	188.51	78
CMJ Power (W)	**Non**	**2325.76**	**354.34**	**31**
	OlyWSC	**2123.54**	**394.20**	**79**
CMJ Scaled Power (W/kg)	**Non**	**37.75**	**4.69**	**31**
	OlyWSC	**35.49**	**5.98**	**79**
CMJ Velocity (m/s)	**Non**	**2.44**	**.23**	**31**
	OlyWSC	**2.28**	**.32**	**79**

Initial Descriptive Statistics - Females

Initial Descriptive Statistics - Females

Statistical significance is indicated by bolding, $p < 0.05$.

Strength and Power

Age-Adjusted Peak Isometric Squat Force (Kg) ANCOVA – **Males**

Tests of Between-Subjects Effects

Dependent Variable: Iso Squat Force (kgf)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	256.813	1	256.813	.549	.461	.006	.113
Group	**19860.495**	**1**	**19860.495**	**42.463**	**.000**	**.325**	**1.000**
Error	41158.889	88	467.715				
Total	4122854.293	91					
Corrected Total	67089.200	90					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Peak Isometric Squat Force (Kg) – **Males**

Dependent Variable: Iso Squat Force (kgf)

Group	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Non	192.551[a]	3.641	185.316	199.786
OlyWSC	225.035[a]	3.115	218.845	231.226

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.17.

Age-Adjusted Peak Isometric Squat Force (Kg) ANCOVA – **Females**

Tests of Between-Subjects Effects

Dependent Variable: Iso Squat Force (kgf)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	**15119.506**	**1**	**15119.506**	**47.552**	**.000**	**.296**	**1.000**
Group	**3767.111**	**1**	**3767.111**	**11.848**	**.001**	**.095**	**.927**
Error	35928.821	113	317.954				
Total	2652399.452	116					
Corrected Total	51606.913	115					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Peak Isometric Squat Force (Kg) – **Females**

Dependent Variable: Iso Squat Force (kgf)

Group	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Non	159.684[a]	3.331	153.085	166.283
OlyWSC	146.107[a]	1.963	142.218	149.995

a. Covariates appearing in the model are evaluated at the following values: Test Age = 22.78.

Age-Adjusted Relative Isometric Squat Force (Kg/Kg) ANCOVA – **Males**

Tests of Between-Subjects Effects

Dependent Variable: Scaled Iso Squat (kg)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	.024	1	.024	.533	.467	.006	.112
Group	**.796**	**1**	**.796**	**17.550**	**.000**	**.166**	**.985**
Error	3.993	88	.045				
Total	800.015	91					
Corrected Total	4.835	90					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Relative Isometric Squat Force (Kg/Kg) – **Males**

Dependent Variable: Scaled Iso Squat (kg)

Group	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Non	2.839[a]	.036	2.767	2.910
OlyWSC	3.044[a]	.031	2.983	3.105

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.17.

Age-Adjusted Relative Isometric Squat Force (Kg/Kg) ANCOVA – **Females**

Tests of Between-Subjects Effects

Dependent Variable: Scaled Iso Squat (kg)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	**3.232**	**1**	**3.232**	**41.570**	**.000**	**.269**	**1.000**
Group	**.327**	**1**	**.327**	**4.210**	**.042**	**.036**	**.530**
Error	8.786	113	.078				
Total	725.580	116					
Corrected Total	12.018	115					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Relative Isometric Squat Force (Kg/Kg) – **Females**

Dependent Variable: Scaled Iso Squat (kg)

Group	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Non	2.573[a]	.052	2.470	2.676
OlyWSC	2.446[a]	.031	2.386	2.507

a. Covariates appearing in the model are evaluated at the following values: Test Age = 22.78.

Age-Adjusted Static Jump Height (cm) ANCOVA – **Males**

Tests of Between-Subjects Effects

Dependent Variable: SJ Height (cm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	58.077	1	58.077	2.119	.149	.024	.302
Group	**563.319**	**1**	**563.319**	**20.553**	**.000**	**.193**	**.994**
Error	2357.064	86	27.408				
Total	196997.898	89					
Corrected Total	2922.037	88					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Static Jump Height (cm) – **Males**

Dependent Variable: SJ Height (cm)

Group	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Non	43.331[a]	.927	41.489	45.174
OlyWSC	48.879[a]	.734	47.419	50.339

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.31.

Age-Adjusted Static Jump Height (cm) ANCOVA – **Females**

Tests of Between-Subjects Effects

Dependent Variable: SJ Height (cm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	**426.245**	**1**	**426.245**	**25.456**	**.000**	**.211**	**.999**
Group	**157.937**	**1**	**157.937**	**9.432**	**.003**	**.090**	**.860**
Error	1590.716	95	16.744				
Total	109572.535	98					
Corrected Total	2057.066	97					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Static Jump Height (cm) – **Females**

Dependent Variable: SJ Height (cm)

Group	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Non	35.240[a]	.804	33.644	36.835
OlyWSC	32.276[a]	.497	31.289	33.262

a. Covariates appearing in the model are evaluated at the following values: Test Age = 22.46.

Age-Adjusted Static Jump Power (W) ANCOVA – **Males**

Tests of Between-Subjects Effects

Dependent Variable: SJ Power (W)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	182947.314	1	182947.314	1.326	.253	.016	.207
Group	**4698455.275**	**1**	**4698455.275**	**34.064**	**.000**	**.289**	**1.000**
Error	11586125.04	84	137930.060				
Total	736384133.5	87					
Corrected Total	16440766.83	86					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Static Jump Power (W) – **Males**

Dependent Variable: SJ Power (W)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	2572.167[a]	65.630	2441.654	2702.680
OlyWSC	3081.619[a]	53.090	2976.044	3187.193

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.27.

Age-Adjusted Static Jump Power (W) ANCOVA – **Females**

Tests of Between-Subjects Effects

Dependent Variable: SJ Power (W)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	**2147540.702**	**1**	**2147540.702**	**18.464**	**.000**	**.166**	**.989**
Group	**1495753.131**	**1**	**1495753.131**	**12.860**	**.001**	**.121**	**.944**
Error	10816643.54	93	116307.995				
Total	379266408.5	96					
Corrected Total	13594335.13	95					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Static Jump Power (W) – **Females**

Dependent Variable: SJ Power (W)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	2157.128[a]	67.033	2024.014	2290.242
OlyWSC	1867.094[a]	42.047	1783.597	1950.592

a. Covariates appearing in the model are evaluated at the following values: Test Age = 22.47.

Age-Adjusted Static Jump Relative Power (W/Kg) ANCOVA – **Males**

Tests of Between-Subjects Effects

Dependent Variable: SJ Scaled Power (W/kg)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	**113.530**	**1**	**113.530**	**5.019**	**.028**	**.056**	**.601**
Group	**257.351**	**1**	**257.351**	**11.377**	**.001**	**.119**	**.915**
Error	1900.081	84	22.620				
Total	142943.620	87					
Corrected Total	2183.711	86					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Static Jump Relative Power (W/Kg) – **Males**

Dependent Variable: SJ Scaled Power (W/kg)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	37.970[a]	.840	36.299	39.641
OlyWSC	41.740[a]	.680	40.388	43.092

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.27.

Age-Adjusted Static Jump Relative Power (W/Kg) ANCOVA – **Females**

Tests of Between-Subjects Effects

Dependent Variable: SJ Scaled Power (W/kg)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	**403.083**	**1**	**403.083**	**15.640**	**.000**	**.144**	**.975**
Group	**203.025**	**1**	**203.025**	**7.877**	**.006**	**.078**	**.793**
Error	2396.891	93	25.773				
Total	103092.342	96					
Corrected Total	2867.674	95					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Static Jump Relative Power (W/Kg) – **Females**

Dependent Variable: SJ Scaled Power (W/kg)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	34.705[a]	.998	32.723	36.686
OlyWSC	31.326[a]	.626	30.083	32.568

a. Covariates appearing in the model are evaluated at the following values: Test Age = 22.47.

Age-Adjusted Counter Movement Jump Height (cm) ANCOVA – **Males**

Tests of Between-Subjects Effects

Dependent Variable: CMJ Height (cm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	74.503	1	74.503	2.330	.130	.024	.327
Group	**361.161**	**1**	**361.161**	**11.296**	**.001**	**.108**	**.914**
Error	2973.434	93	31.972				
Total	280841.903	96					
Corrected Total	3336.006	95					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Counter Movement Jump Height (cm) – **Males**

Dependent Variable: CMJ Height (cm)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	51.154[a]	.968	49.233	53.076
OlyWSC	55.476[a]	.769	53.948	57.003

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.29.

Age-Adjusted Counter Movement Jump Height (cm) ANCOVA – **Females**

Tests of Between-Subjects Effects

Dependent Variable: CMJ Height (cm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	**802.860**	**1**	**802.860**	**27.790**	**.000**	**.212**	**.999**
Group	**359.235**	**1**	**359.235**	**12.434**	**.001**	**.108**	**.937**
Error	2975.739	103	28.891				
Total	142909.835	106					
Corrected Total	3938.027	105					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Counter Movement Jump Height (cm) – **Females**

Dependent Variable: CMJ Height (cm)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	39.618[a]	1.099	37.439	41.798
OlyWSC	35.156[a]	.601	33.963	36.349

a. Covariates appearing in the model are evaluated at the following values: Test Age = 22.62.

Age-Adjusted Counter Movement Jump Power (W) ANCOVA – **Males**

Tests of Between-Subjects Effects

Dependent Variable: CMJ Power (W)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	380532.123	1	380532.123	2.070	.154	.022	.296
Group	**5027388.014**	**1**	**5027388.014**	**27.343**	**.000**	**.227**	**.999**
Error	17099259.77	93	183863.008				
Total	1054781996	96					
Corrected Total	22215021.87	95					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Counter Movement Jump Power (W) – **Males**

Dependent Variable: CMJ Power (W)

Group	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Non	2971.610[a]	73.382	2825.889	3117.331
OlyWSC	3481.419[a]	58.349	3365.550	3597.288

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.29.

Age-Adjusted Counter Movement Jump Power (W) ANCOVA – **Females**

Tests of Between-Subjects Effects

Dependent Variable: CMJ Power (W)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	**3441033.233**	**1**	**3441033.233**	**29.582**	**.000**	**.217**	**1.000**
Group	**2069968.463**	**1**	**2069968.463**	**17.795**	**.000**	**.143**	**.987**
Error	12446408.30	107	116321.573				
Total	539816901.8	110					
Corrected Total	16797810.64	109					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Counter Movement Jump Power (W) – **Females**

Dependent Variable: CMJ Power (W)

Group	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Non	2408.792[a]	63.130	2283.645	2533.940
OlyWSC	2090.961[a]	38.837	2013.971	2167.951

a. Covariates appearing in the model are evaluated at the following values: Test Age = 22.49.

Age-Adjusted Counter Movement Jump Relative Power (W/Kg) ANCOVA – **Males**

Tests of Between-Subjects Effects

Dependent Variable: CMJ Scaled Power (W/kg)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
TestAge	**197.824**	**1**	**197.824**	**6.444**	**.013**	**.065**	**.710**
Group	**179.032**	**1**	**179.032**	**5.832**	**.018**	**.059**	**.666**
Error	2855.098	93	30.700				
Total	204914.476	96					
Corrected Total	3125.114	95					

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Counter Movement Jump Relative Power (W/Kg) – **Males**

Dependent Variable: CMJ Scaled Power (W/kg)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	44.009[a]	.948	42.126	45.892
OlyWSC	47.052[a]	.754	45.554	48.549

a. Covariates appearing in the model are evaluated at the following values: Test Age = 23.29.

Age-Adjusted Counter Movement Jump Relative Power (W/Kg) ANCOVA – **Females**

Tests of Between-Subjects Effects

Dependent Variable: CMJ Scaled Power (W/kg)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
TestAge	**679.921**	**1**	**679.921**	**26.230**	**.000**	**.197**	**26.230**	**.999**
Group	**309.222**	**1**	**309.222**	**11.929**	**.001**	**.100**	**11.929**	**.928**
Error	2773.560	107	25.921					
Total	147162.179	110						
Corrected Total	3567.137	109						

b. Computed using alpha = .05

Age-Adjusted Descriptive Statistics Counter Movement Jump Relative Power (W/Kg) – **Females**

Dependent Variable: CMJ Scaled Power (W/kg)

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non	38.920[a]	.942	37.052	40.789
OlyWSC	35.036[a]	.580	33.886	36.185

a. Covariates appearing in the model are evaluated at the following values: Test Age = 22.49.

Physical Requirements and Training Considerations

Strength and Power

The purpose of a strength and conditioning program for mogul skiers is to, reduce the incidence of injury, optimize both peak and relative lower-body strength (primarily eccentric), peak and relative power, develop anaerobic metabolism such that the athlete is able compete at a high level while having a competent aerobic capacity so that the athlete can tolerate the low levels of stress for an extended period that come with training.

Physical preparation of trunk, shoulder girdle, arms, and neck should not be neglected as these areas account for 57% of all injuries (Bullock, Incidence of Injury in United States World Cup Mogul Skiers from 2014-2018, 2018). Perhaps in this case the athletic development coach needs to consider not only the best-case scenarios but also the worst – the inevitable crash. Adding a substantial amount of strength to the trunk, shoulder, arms, and neck can help protect the athlete in the event of a fall. Secondarily, a lean yet muscular athlete will possess more "body armor" to soften a blow from ice or snow and protect connective structures, organs, or bones.

As stated previously, the relative input percentage for each of the muscles involved in mogul skiing is as follows (Sands & Bullock, EMG of Mogul Skiers, 2018):

- Erector Spinae: 10-15%
- Glute Max: 5-10%
- VMO: 30-35%
- Rectus Femoris: 40-45%
- Biceps Femoris: 5-10%

Therefore, the athletic development coach should seek to prepare the tissues associated with the high loads (both structural and metabolic) found in mogul skiing. Strength and power exercises such as the front squat, back squat, and leg press – in addition to their single leg or supported variations, as well as pliometric (rapid eccentric) and plyometric (rapid eccentric/concentric coupling) activities are great tools to help prepare the mogul skier for training and competition.

Based on data from Bullock and Sands (2018) we know definitively that a mogul skier's ability to efficiently absorb force (eccentric muscle action) in a very rapid manner – approximately 3-4 bumps or contacts every second - is critical to the success of the athlete. Note that eccentric muscle action is not exclusively employed but rather critical component of the overall preparatory process. Other muscle actions should not be neglected.

Eccentric Muscle Action

To date, there is a substantial amount of literature on the use of eccentric strength training as it relates to force and power production. To be clear, eccentric muscle action occurs when the muscle is forcibly lengthened or elongated; and when directly compared, eccentric muscle actions can produce greater force in amounts estimated to be 20-60% greater than those forces generated during concentric actions (Mike, Kerksick, & Kravitz, 2016).

Evidence surrounding muscle damage (loss of force production, increased soreness, and myocellular protein accumulation in the serum [e.g., creatine kinase, myoglobin, etc.] as well as Z-disk streaming) are routinely reported to a greater extent

when eccentric actions are completed. However, eccentric resistance training incorporating submaximal, maximal (100% one repetition maximum [1RM]), or supramaximal (typically 102–130% 1RM) training loads has been shown to stimulate greater increases in maximal muscle strength as compared to traditional activities involving both concentric and eccentric action (Mike, Kerksick, & Kravitz, 2016). The athletic development coach should therefore be cognizant of when and how they use this strategy.

Studies show a relationship between improved eccentric strength and improved athletic performance. For example, in fast movement (e.g., mogul skiing), preactivation of muscles is observed between the onset of electromyographic signal and the subsequent limb movement (Sands & Bullock, 2018). In addition, preactivation of muscle immediately enhances sensitivity of muscle spindles, leading to improved regulation of reflex potentiation and stiffness throughout the subsequent eccentric phase (Mike, Kerksick, & Kravitz, 2016). In addition, although all muscle actions elicit a hypertrophic response, eccentric muscle actions may have the greatest effect on skeletal muscle size. Finally, from a neural perspective, eccentric training produces a heightened response when compared to concentric training. These neural adaptations likely include spinal and cortical mechanisms (i.e., larger excitability and greater involvement of brain areas) and are areas in need of greater research. Of note, despite the heightened response, lower levels of neural activation have been shown in eccentric actions when compared to concentric creating a much greater force-to-activation ratio. (Mike, Kerksick, & Kravitz, 2016).

Currently there are many ways the athletic development coach can and should incorporate eccentric training into the physical preparation program of the mogul skier.

1) Physical rehabilitation athletes can derive benefits from eccentric training, starting first with the known cross-education effect or the transfer of strength gains unilaterally from one limb/side to the other. Protocols using cross education have been shown to successfully improve quadriceps strength in the limbs of healthy uninjured participants, although the exact mechanism is still not yet fully explained it is believed that strength grains may have occurred because of enhanced neural activity.
2) In the early general physical preparatory (GPP) phase the athletic development coach may use a slow/super-slow method. When using this method, the athlete executes an exaggerated slow-speed eccentric phase while concentrically lifting the bar explosively. A load ranging from 60 to 85% 1RM is commonly used with eccentric action durations ranging from 2 to 8 seconds, depending on load assignment and type of movement.
3) In the late GPP phase, once basic levels of strength and stamina are achieved and in the most advanced athletes, the athletic development coach may use a supramaximal method. When employing this technique, the athlete focuses their effort on eccentric control of a load greater than their 1RM; typically, 102 to 130% of 1RM. Upon completion of the descent a significant portion (if not all) of the load is removed prior to the athlete performing the concentric action. This technique places a very large demand on the athlete's nervous system and therefore can elicit rapid periods of overreaching and potential overtraining.
4) During the specific physical preparatory (SPP) phase the athletic development coach may choose to employ high velocity accentuated eccentrics. This can be done using several modalities, including: 1) fly wheel training, 2) accentuated eccentrically loaded counter movement jumps, 3) banded eccentric accelerations of traditional exercises, or 4) pliometric or plyometric training methods. When sequencing eccentric-concentric muscle actions with an accentuated eccentric load, as compared to body mass loaded, in highly trained athlete's results have shown significant increases in displacement, peak velocity, peak force, and peak power (Sheppard, et al., 2008).

It is important to note that in the sport of mogul skiing eccentric loads are important for the lower body and also the trunk. The phenomenon known as Mogul Back appears to be a result of high load, high velocity eccentric muscle action of the erector spinae when the athlete contacts the face of the bump and attempts to maintain an upright position that remains perpendicular to the slope of the hill (Sands & Bullock, EMG of Mogul Skiers, 2018)l. While the loads, velocities, and volumes experienced during training and competition may be difficult to replicate safely in a gym setting the athletic development coach should employ the above means (in addition to other muscle actions) in preparation for the demands of the sport. It is the opinion of the author that the effects of mogul back can be reduced through training and on-hill progression resulting in more productive training opportunities and reduced likelihood of injury.

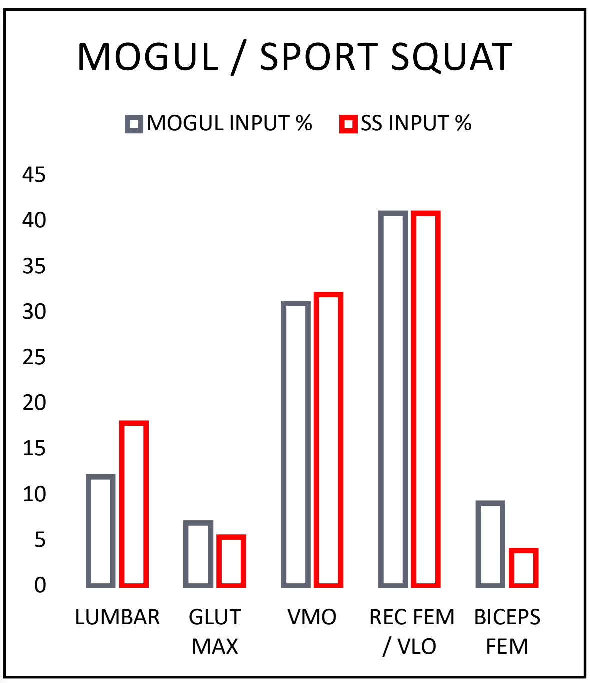
Repeated Bout Effect

A phenomenon worth noting as it relates mogul skiers is the repeated bout effect. The repeated bout effect can be described as two bouts of repeated eccentric exercise which are more than one week apart (Pettitt, Symons, Eisenman, Taylor, & White, 2005). Although the mechanisms of the repeated bout effect aren't entirely understood, some notable results appear to be decrements in muscle force production, eccentric induced myofibril damage, and altered length tension relationships (Pettitt, Symons, Eisenman, Taylor, & White, 2005).

According to Pettitt et al. (2005), the repeated bout effect evokes three primary implications for the strength and conditioning coach: 1) the use of a larger variety of single joint exercises with the movement of the joint ending in full range of motion may be applicable due to the exposure of a larger number of muscles to strain at longer lengths (with the hope of better global protection from future exercise induced muscle damage), 2) the effects of repeated bout effect, whether induced through sport training or physical preparation can and will result in delayed onset muscle soreness (DOMS). Exposures should be implemented to prevent and/or lessen soreness, and/or hasten recovery from soreness; 3) eccentric exercise at long length causes a shift in torque-angle relations and that effect on dynamic correspondence should be considered when applying SPP methods.

Special Exercises for Strength and Power

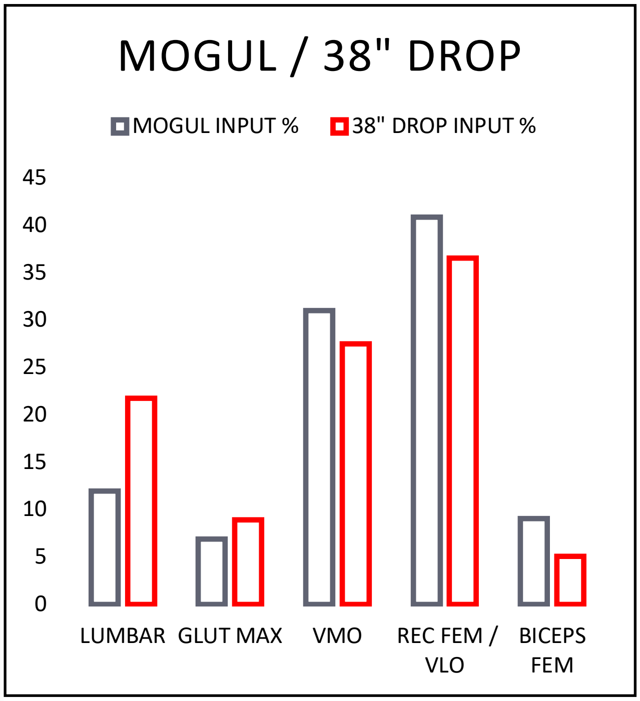
In addition to the above stated exercises and techniques, Bullock and Sands (2018), have evaluated three special strength and power exercises relative to SPP using EMG. They are described below. It should be noted that these are not the only techniques the practitioner should or could use during the SPP period.



Above: Skiing in moguls and Sport Squat EMG comparison (Sands & Bullock, EMG of Mogul Skiers, 2018).

The rear sport squat is an exercise whereby the athlete performs a squat at a partial (or specific) range of motion using a high velocity.

As seen at the left this exercise has a similar input % as skiing in moguls.

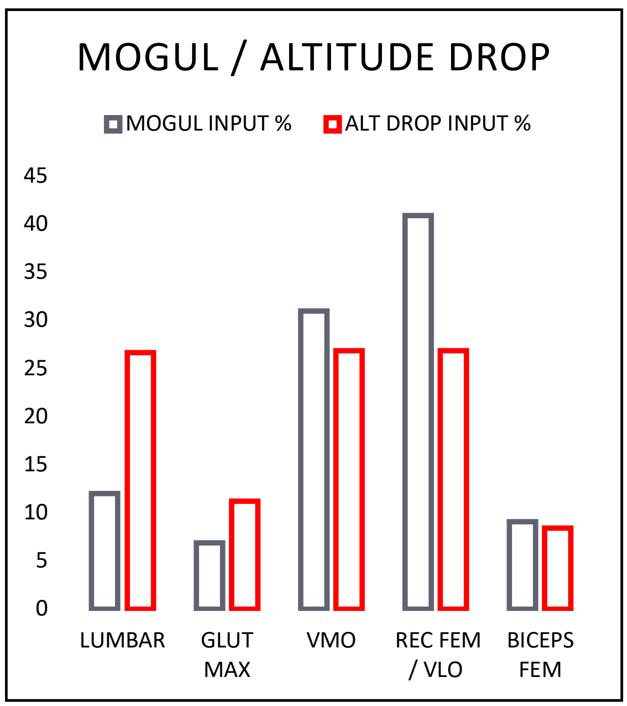


Above: Skiing in moguls and Drop Jump EMG comparison (Sands & Bullock, EMG of Mogul Skiers, 2018).

The drop jump, performed from 38 inches in women and 48 inches in men, is performed by stepping from the box and landing in a narrow stance with the hands wide simulating the landing position from a jump or contact with the face of the mogul.

As seen at the left, this has a similar input % to skiing in moguls but has yet to be evaluated using EMG for landing from a jump.

G-forces from this exercise are between 8 and 10 G's; similar to those experienced by athletes upon landing following aerial maneuvers in Zermatt, Switzerland (Sands & Bullock, Acclerometry of Mogul Skiers, 2018).



Above: Skiing in moguls and Altitude Drop EMG comparison (Sands & Bullock, EMG of Mogul Skiers, 2018).

The altitude drop is performed by stepping from a platform 7-8 feet in height and landing in narrow stance with the hands wide on an 8-inch foam pad simulating a landing position following a jump on a chopped landing.

As seen at the left, this exercise has a somewhat similar input % to skiing in moguls. This exercise has yet to be evaluated using EMG for landing from a jump; which is perhaps its greatest application to SPP.

Energy System Development

The sport of mogul skiing is a high intensity, short duration sport that relies primarily on the ATP/phosphogenic and glycolytic energy systems. Evidence collected from training runs in Zermatt, Switzerland supports this view. While competition and the act of skiing on a full mogul course rely heavily upon these energy systems the practitioner should not discount the other stresses of training that accompany the sport. These include: hiking at the water ramp, hiking a jump on snow, longer out runs, skate skiing out runs, or significant changes in altitude.

Therefore, the optimal range of aerobic fitness in mogul skiers will remain a matter of debate. It seems logical from the data available that mogul skiers should periodize their approach to training in preparation for the stresses associated with subsequent preparatory blocks and then capitalize upon the cascading effects of the previous.

April	May	June	July	August	September	October	November	December-March
Post Season	Off-Season			Pre-Season				In-Season
General Physical Preparation				Specific Physical Preparation				Accentuation
Active Rest	Eccentric	Isometric	Concentric	Str/Spd	Supra max	Str/Spd	Concentric	Realization
Example of Variables Used for Energy System Development								
Bike, Hike, Row, etc.		Bike, Hike, Sprint, etc.		Special Exercises, Bike, Sprint				Bike, Walk
Zone 1, 2, 3		Zone 1,4,3	Zone 2,4,3	Zone 2,4,3				Zone 1, 2
20-90 minutes (accumulating)		20-60 minutes (undulating)		10-60 minutes (undulating)				Max 20 minutes

Above: Sample periodized training plan for mogul skiing (does not include sport training). A complete example of a periodized plan can be found in appendix G.

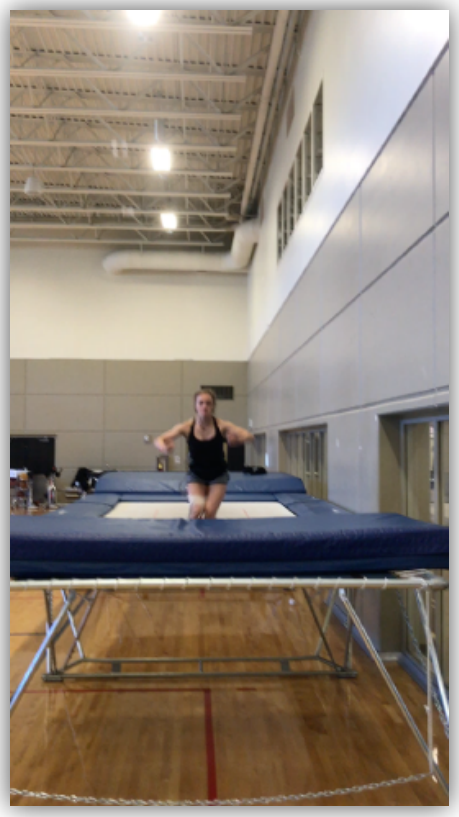
Special Exercises for Energy System Development

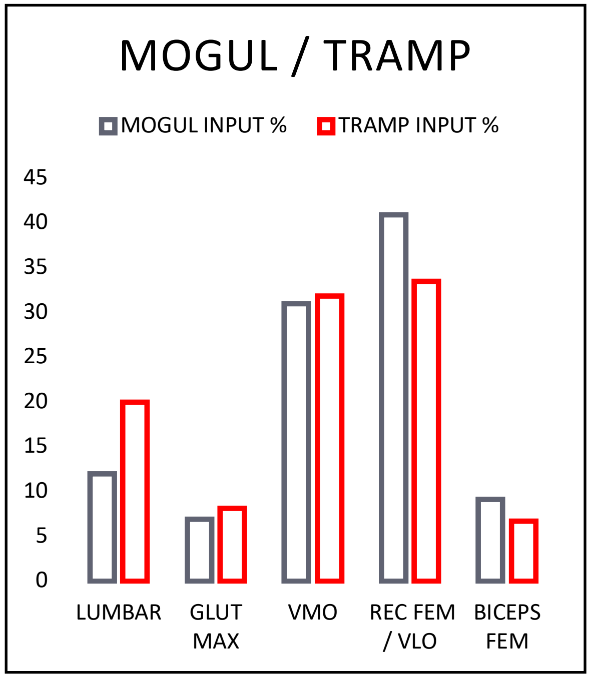
Bullock and Sands (EMG of Mogul Skiers, 2018), have evaluated five special energy system development exercises relative to SPP using EMG. They are described below. It should be noted that these are not the only techniques the practitioner should or could use during the SPP period.

The simulated mogul course, as shown previously in the sections on Electromyography and Energy Systems, is highly similar to the actual act of skiing moguls. The energy system demands strongly resemble measured training runs and the motor pattern, with the exception, of the forward push to move down the stairs, make this special exercise a wonderful alternative to skiing in moguls when snow is unavailable.

Given the similarities in both energy system demands and motor pattern this drill may be used to both develop the physical capacities for the sport as well as the actual sport skill of skiing in moguls.

The drill in its test form, is performed by descending 13 stairs, moving left to right as if skiing moguls, jumping back to the top, descending the stairs a second time, jumping back to the top, and descending the stairs for a third and final time. As a drill for energy system development the practitioner may prescribe portions of this test performed in interval fashion or intermixed with other drills to prepare the athlete for the demands of the competition.

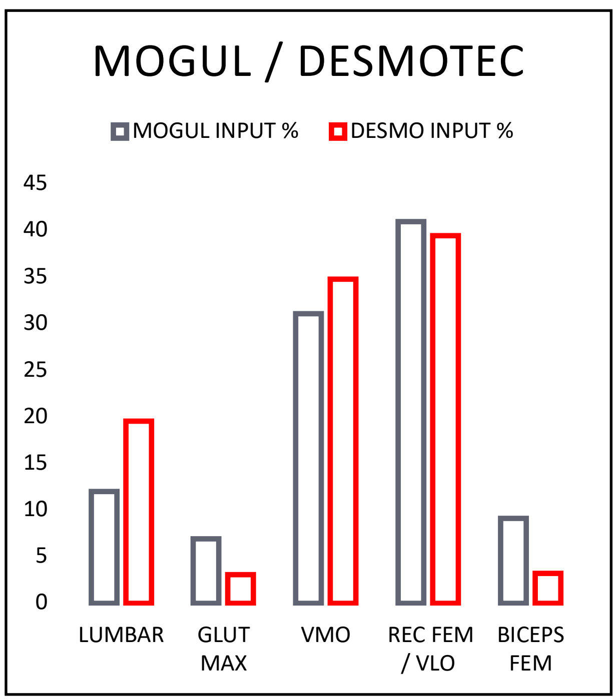




Above: Skiing in moguls and Trampoline Moguls EMG comparison (Sands & Bullock, EMG of Mogul Skiers, 2018).

The trampoline moguls are an exercise whereby the athlete adopts a mogul specific stance and with the upper torso, arms, and head remaining still and level performs a series of high velocity squats moving left to right while compressing and absorbing the bed of the trampoline.

As seen at the left this exercise has a similar input % as skiing in moguls.

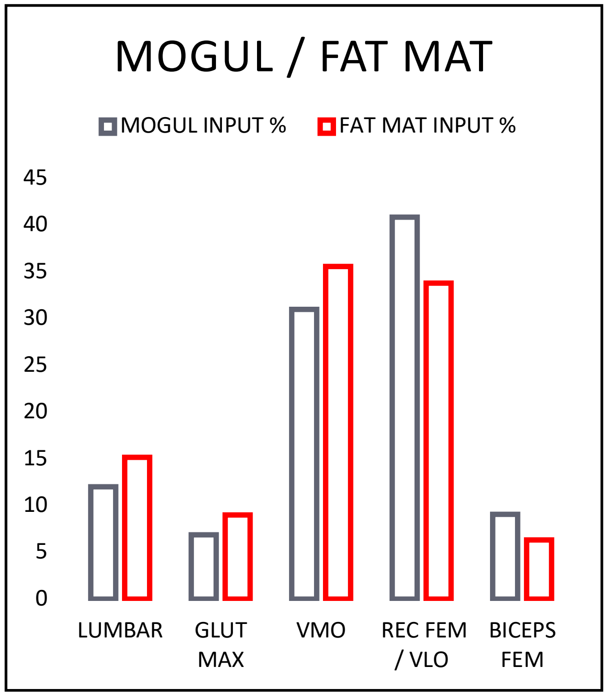


Above: Skiing in moguls and Desmotec Sport Squat EMG comparison (Sands & Bullock, EMG of Mogul Skiers, 2018).

The Desmotec sport squat is an exercise whereby the athlete adopts a mogul specific stance and with the upper torso, arms, and head remaining still and level performs a series of high velocity squats absorbing then overcoming the load of the fly wheel.

As seen at the left this exercise has a similar input % as skiing in moguls.

It is important to note this exercise was evaluated with EMG using the shoulder harness thus increasing the load on the lumbar with the hope of addressing the Mogul Back phenomenon.

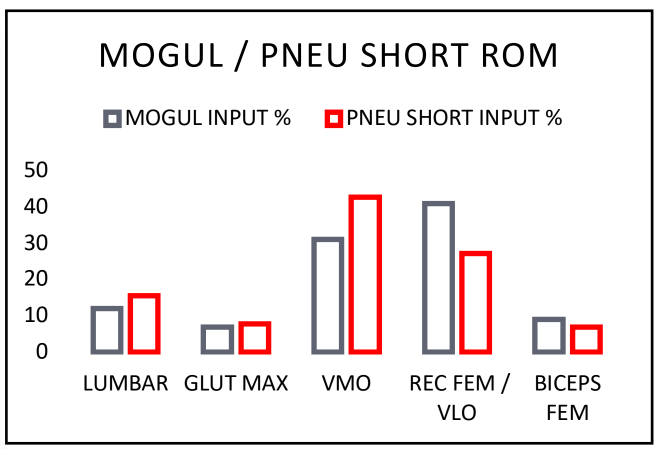


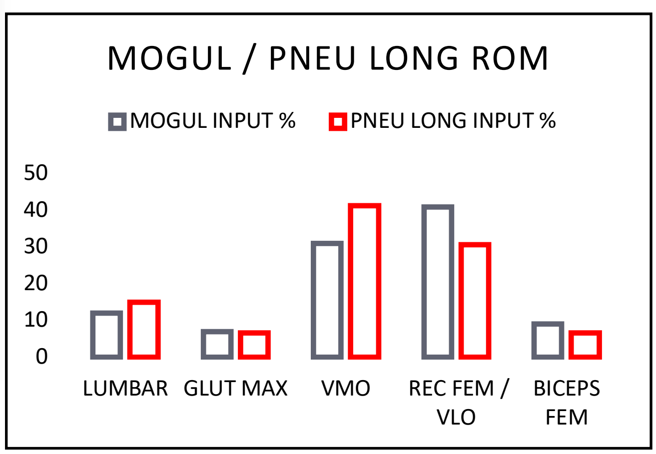
Above: Skiing in moguls and Fat Mat Moguls EMG comparison (Sands & Bullock, EMG of Mogul Skiers, 2018).

Very similar in technique to the trampoline moguls, the fat mat moguls are an exercise whereby the athlete adopts a mogul specific stance and with the upper torso, arms, and head remaining still and level performs a series of high velocity squats while compressing and absorbing the foam of the fat mat.

As seen at the left this exercise has a similar input % as skiing in moguls.

Right: Skiing in moguls and Pneubounder EMG comparison (Sands & Bullock, EMG of Mogul Skiers, 2018; Sands & Bullock,





The Pneubounder is an exercise whereby the athlete adopts a mogul specific stance and with the upper torso, arms, and head remaining still and level performs a series of high velocity squats while compressing and absorbing the pneumatic platform.

This exercise can be performed using both a short and quick pulse as well as a long, ranging motion.

As seen at the left both variations of this exercise have a similar input % as skiing in moguls; with the long range of motion being slightly closer to skiing in moguls.

Physical Threshold Ranges

The question of how strong is strong enough in the sport of mogul skiing is one in which the author has pondered since arrival at US Ski and Snowboard. This question can also be applied to many other traits such as power, speed, or even body weight. While it is difficult to set a minimum and/or maximum threshold and apply it to the masses, it is helpful to have some benchmarks to guide the coach and athlete in athlete preparation. It is the belief of the author that the information below be used with extreme caution when making training decisions. The practitioner should always analyze then aggregate rather than aggregate then analyze when it comes to the performance of the individual.

Current data from Sands (2017) and coach's observations made over the 2017-2018 and 2018-2019 seasons have resulted in the following characteristic ranges for both males and females:

US SKI AND SNOWBOARD MEN'S PHYSICAL THRESHOLD RANGES		
TEST	**LOWER RANGE**	**UPPER RANGE**
Body Mass (Kg)	70.77	77.33
Sum of Seven (mm)	41.32	56.88
Scaled Iso Squat (kg)	2.82	3.26
Static Jump – F (N)	1570.11	1873.07
Static Jump – P (W)	2709.08	3424.48
CMJ – F (N)	1735.89	2316.43
CMJ – P (W)	3047.94	3870.83
CMJ – Relative (W/Kg)	42.2	50.9
CMJ – Velocity (m/s)	2.62	3.10
Simulated Mogul Course**		
Speed (seconds)	29.87	33.22
Peak Blood Lactate (mmol/L)	9.81	13.64
Heart Rate (% of Max)	89	94
Recovery Rate (% after 3 minutes)	52	63
**Upper range and lower range calculated using mean +/- one standard deviation from data on Oly/WSC participants.*		
***Data from all male athletes.*		

US SKI AND SNOWBOARD WOMEN'S PHYSICAL THRESHOLD RANGES		
TEST	**LOWER RANGE**	**UPPER RANGE**
Body Mass (Kg)	54.64	65.16
Sum of Seven (mm)	70.17	100.24
Scaled Iso Squat (kg)	2.14	2.82
Static Jump – F (N)	1118.59	1408.71
Static Jump – P (W)	1528.25	2271.15
CMJ – F (N)	1246.22	1623.24
CMJ – P (W)	1729.34	2517.75
CMJ – Relative (W/Kg)	29.41	41.47
CMJ – Velocity (m/s)	1.96	2.60
Simulated Mogul Course**		
Speed (seconds)	30.97	35.42
Peak Blood Lactate (mmol/L)	9.72	14.25
Heart Rate (% of Max)	90	97
Recovery Rate (% after 3 minutes)	52	63
**Upper range and lower range calculated using mean +/- one standard deviation from data on Oly/WSC participants.*		
***Data from all female athletes.*		

SECTION #9

NUTRITION

Broadly, nutrition for an athlete affects both health and performance: the foods and drinks that are consumed in training and competition will affect how well an individual can train and compete. A good diet will help support consistent intensive training without the athlete succumbing to excessive fatigue, illness, or injury. Good food choices can also promote adaptations to the training stimulus, enhance recovery between workouts and training, and speed tissue repair from minor injuries (Robson-Ansley, Gleeson, & Ansley, 2013).

US Ski and Snowboard team athletes experience a variety of nutritional challenges and employ an equal variety of fueling strategies and resources to fuel for optimal performance. Athletes on the World Cup tour have both the benefit and challenge of experiencing a variety of foods from different cultures. For example, over the course of one season an athlete might experience cuisine from North America, Eastern and Western Europe, Japan, China, Korea, Australia, and South America. The coach and practitioner should acknowledge this fact as the athlete will be exposed to unfamiliar foods during both training and competitive periods.

While at the Center of Excellence (COE) athletes have the benefit of professional chefs and dieticians preparing meals designed to fuel them for optimal performance. From time to time these resources are available during periods of travel such as at events like the Olympic Winter Games, World Ski Championships, World Cup competition in the United States, or training camps of extended length.

Fueling the athlete during extended periods of travel may not mean simply the exposure to foreign foods but the limited availability of healthy food choices during transit. As stated previously, travel to and from training and competition venues is extensive and athletes, during those periods, will likely be fueling on the plane, in the airport, or during a stop between train stations or car refueling. Given the above stated circumstances, it is critical athletes are educated on proper fueling and supplementation strategies to support their physical preparation and competition as well as their individual needs.

To accomplish this goal the High-Performance staff and dieticians employ many educational strategies; these include: 1) individual nutritional counseling, 2) team educational sessions, 3) individual testing for deficiencies, 4) food preparation courses, 5) food purchasing courses, and 6) dissemination of informal literature (both applied and scientific).

Fueling for Preparation and Competition

Mogul skiing relies primarily on the development of power through anaerobic energy, the phosphocreatine, and glycolytic systems for energy. Biomechanical, neuromuscular, and metabolic factors all influence performance. As stated previously in the section on energy system demands, mogul skiing is a sprint event with demands very like that of the 200m sprinter and it has been demonstrated that elite sprinters have muscles composed predominantly of fast-twitch fiber (Tipton, Jeukendrup, & Hespel, 2007). Based on this similarity, there are some nutritional considerations for mogul skiers that include:

- maintaining energy levels during training
- quick recovery from training
- optimizing training adaptations with nutrition; achieving a high power-to-weight ratio, thus maximizing muscle mass and maintaining low body fat
- staying focused, sharp and maintaining concentration during competition days
- improved reaction times

Training of mogul skiers is focused on developing the lean body mass capable of generating the strength and power necessary to carry the athlete as rapidly and mistake-free as possible down the course. Thus, total caloric and macronutrient variables should be given careful attention.

Carbohydrates

Carbohydrate is the key macronutrient for energy supply and athletes should be conscious of meeting this need. Generally, carbohydrate provides important but short-term supply of energy for training that must be replenished each day. The diet of the athlete should supply enough carbohydrate to fuel his or her training as well as optimize the recovery of muscle and liver stores of glycogen between training session (Robson-Ansley, Gleeson, & Ansley, 2013).

General targets can be provided for carbohydrate needs based on the athlete's body mass (BM) and the demands of his or her training volume and intensity. Broadly, "…recommendations for carbohydrate (CHO) ingestion to optimize fatigue management and maximize recovery following training are: 1g CHO · kg $BM^{-1} \cdot hour^{-1}$ as soon as possible (e.g. within 4 h) after exercise; 5–7g CHO · kg $BM^{-1} \cdot day^{-1}$ of bodyweight for recovery within 24 hours from light to moderate-intensity training; 7–10g CHO · kg $BM^{-1} \cdot day^{-1}$ for recovery from moderate- to heavy endurance training; 10–12g CHO · kg $BM^{-1} \cdot day^{-1}$ for daily recovery from extreme exercise training sessions (more than 4 hours · day^{-1})" (Robson-Ansley, Gleeson, & Ansley, 2013, p. 1414).

Protein

Protein foods are important for building and repairing muscles and a varied diet containing everyday foods will generally supply more than enough protein (Robson-Ansley, Gleeson, & Ansley, 2013). Additionally, well-chosen vegetarian diets can also meet protein needs; an important consideration for the 2018-2019 team as the team currently has a few athletes requiring such a consideration. Optimal protein balance is a desirable goal of the recovery phase to overturn the increased rates of protein breakdown that occur during and after exercise, and to promote protein synthesis, net protein gain, repair, and adaptation following the exercise stimulus (Robson-Ansley, Gleeson, & Ansley, 2013). According to Robson-Ansley et al (2013), "The current consensus is that no athletes require protein intakes greater than 1.7 g protein · kg $BM^{-1} \cdot day^{-1}$" (p. 1415).

Hydration

Maintaining hydration status is important for performance. Literature suggests that a dehydrated athlete with 2.5% loss of body weight in the form of water can experience up to a 45% loss in the capacity to perform high-intensity exercise (Tipton, Jeukendrup, & Hespel, 2007). “Athletes should aim to drink about 1.2–1.5 liters of fluid for each kilogram of body mass lost in exercise sessions” (Robson-Ansley, Gleeson, & Ansley, 2013, p. 1415). In addition to water intake, athlete should utilize electrolyte replacement following exercise in which high sweat loss takes place. Special attention should be given to periods of travel, high elevation, extreme temperatures, and the consumption of alcohol when considering and monitoring the hydration of athletes See Appendix E for hydration monitoring details.

Competition Day

When considering fueling for competition day, research on sprinters reveals that the influence of acute nutritional intake is likely not as influential to performance as compared to their endurance counterparts. The duration of a run alone prevents such an influence (Tipton, Jeukendrup, & Hespel, 2007). What should be considered is the duration of the typical competition day and the variable amounts of waiting that result. See the chart below for an example:

SINGLE MOGUL COMPETITION	DUAL MOGUL COMPETITION
9:00am – Qualification Inspection / Training	10:30am – Inspection/ Training #1
10:10am – Qualification #1 (All athletes)	12:15pm – Preliminary Round #1
11:45am – Qualification #2 (Top 20 from Q1)	12:45pm – Preliminary Round #2
2:30pm – Final Inspection / Training	1:30pm – Final Round #1 (Round of 16)
4:30pm – Final #1 (Top 16 from Q2)	1:50pm – Final Round #2 (Round of 8)
5:30pm – Final #2 (Top 6 from F1)	2:05pm – Final Round #3 (Round of 4)
6:00pm – Awards / Media	2:20pm – Final Round #4 (Round of 2)
	2:50pm – Awards / Media

During the time between runs athletes should remain hydrated, but avoid overdrinking, maintain blood glucose levels (through optimal carbohydrate ingestion), and avoid behaviors, including feeding, that may contribute to discomfort, particularly gastrointestinal discomfort.

Special Considerations

Mogul skiers often encounter extreme cold (temperatures below 0ºC) and high elevation (altitudes in excess 3000m) during training and competition. A consideration the athlete, coach, and practitioner should be cognizant of when attending training camp or competing under such conditions.

Ascent to high elevation causes energy expenditure to increase (Meyer, Manore, & Helle, 2011). According to Meyer et al. (2011), at 4300m basal metabolic rate increase by an average of 10-17% compared to sea level. High altitude exposure is frequently accompanied by weight loss averaging approximately 1.4 kg of body weight per week according to Ansley et al (2007). The cause of such a significant disturbance in basal metabolic rate is a result of changes in energy substrate and gender. At high altitude, energy deficit resulting from inadequate carbohydrate intake can result in increased reliance on protein as metabolic fuel, leading to a negative nitrogen balance and loss of lean tissue (Meyer, Manore, & Helle, 2011). Therefore, athletes should make a point to increase carbohydrate intake to match the increased energy demands. Female athletes respond differently than their male counterparts relying more heavily on fat as fuel at rest and during submaximal exercise. Additionally, women use less blood glucose and glycogen at altitude (Meyer, Manore, & Helle, 2011). Females who suffer from iron deficiency anemia should pay careful consideration to supplementation as those with low iron stores “…have difficulty producing erythrocytes in sufficient quantity and maturity for the production and release of reticulocytes from bone marrow, which contributes to the increase in red cell mass, blood volume, and enhanced oxygen carrying capacity” (Meyer, Manore, & Helle, 2011, p. 128).

Training and competition in the cold may also increase energy requirements. Most of this increase depends on whether thermoregulation can maintain skin and core temperature via protective clothing and physiologic responses (e.g. vasoconstriction and metabolic heat production). Based on the observations of the author, shivering and extreme cold are rare but coaches should be cognizant that such a response increases energy requirements as heat is produced to maintain core body temperature. According to Meyer et al. (2011) weight loss of 3-8% of bodyweight may occur in cold environments with the probable causes related to fluid intake and expenditures. These variables include: 1) large sweat losses, 2) impaired thirst, and 3) limited access to fluids (Meyer, Manore, & Helle, 2011).

Supplementation

There are a few supplements which could be beneficial to the training and performance of the mogul skier. It is important to note that evidence addressed in this section is acquired and applied to mogul skiers; currently there are no studies available on supplementation use for athletes in the sport. US Ski and Snowboard athletes are instructed to use only supplementation in which there is sufficient evidence of efficacy and are not listed on either the United States Anti-Doping Agency (USADA) or World Anti-Doping Agency (WADA) lists.

Creatine

Creatine is natural guanidine compound that occurs in meat and fish. Synthetic creatine, such as creatine monohydrate, is commonly used by athletes who compete in sports that require high strength and power outputs. The effects of creatine intake on strength and power, two of the primary determinants of mogul skiing performance, have been investigated extensively since the early 90's. Results from well controlled laboratory studies consistently indicate that creatine supplementation can enhance power output during short maximal exercise "…in particular during intermittent series (10-30s) of maximal muscle contraction…" (Tipton, Jeukendrup, & Hespel, 2007, p. 10). Typical creatine loading regimens consist of an initial loading phase of 15-20 $g \cdot day^{-1}$ for 4-7 days followed by daily maintenance doses of 2-5$g \cdot day^{-1}$. It should be noted that creatine does result in increased body mass from intracellular water accumulation (Tipton, Jeukendrup, & Hespel, 2007), a fact that should not be overlooked in athletes such as mogul skiers who desire optimal power to mass ratios.

Beta Alanine

Beta Alanine is a non-essential amino acid that is common in many foods, especially meats. Fundamentally, beta-alanine is believed to be the rate limiting substrate for the synthesis of carnosine, an intracellular buffer of H^+ ions that mitigates the decrease in intracellular pH associated with anaerobic metabolism (Tipton, Jeukendrup, & Hespel, 2007). "In theory, increasing skeletal muscle carnosine levels (via beta-alanine supplementation or intense training) should increase buffering capacity, delay fatigue, and increase exercise performance" (Tipton, Jeukendrup, & Hespel, 2007, p. 9).

Caffeine

Caffeine is a very popular stimulant used by many individuals from athletes to the lay person. Caffeine is contained in coffee, tea, chocolate, and other beverages common in skiers such as cola or energy drinks. Caffeine enhances central nervous system drive and improves muscle fiber recruitment (Tipton, Jeukendrup, & Hespel, 2007). Caffeine dose of 1-2 $mg \cdot kg^{-1}$ body mass can have a positive effect on mental alertness (Tipton, Jeukendrup, & Hespel, 2007); thereby shortening reaction time; a trait that is clearly desirable in mogul skiers. The athlete and strength and conditioning practitioner should be aware that frequent high-dose caffeine intake results in a rapid desensitization and will require higher doses to be effective.

Sodium Bicarbonate

Bicarbonate is an important buffer in the blood (Tipton, Jeukendrup, & Hespel, 2007) and has a role in buffering H^+ ions. Sodium bicarbonate ingestion "…is the traditional method of increasing the extracellular buffering capacity…" (Tipton, Jeukendrup, & Hespel, 2007, p. 10). Available literature suggests a dose of between 200 and 300 $mg \cdot kg^{-1}$ body mass 1-2 hours before exercise; doses in excess of 300 $mg \cdot kg^{-1}$ body mass have resulted in gastrointestinal problems. Notably, no current studies have shown an effect on performance in high-intensity exercise lasting less than one minute (Mogul Skiing run lasts 22-27 seconds). Therefore, performance will likely remain unaffected by sodium bicarbonate ingestion.

Alcohol Consumption
In has been the observation of the author that alcohol consumption by many world cup mogul skiers is commonplace. As athletes travel the legal drinking age decreases (below 21 years of age) and the availability of adult beverages becomes much higher. Additionally, celebratory events on the FIS World Cup Tour frequently involve champagne or local favorites (e.g., sake in Japan). As such, the social temptation may be unavoidable and athletes should use best practices when managing their consumption.

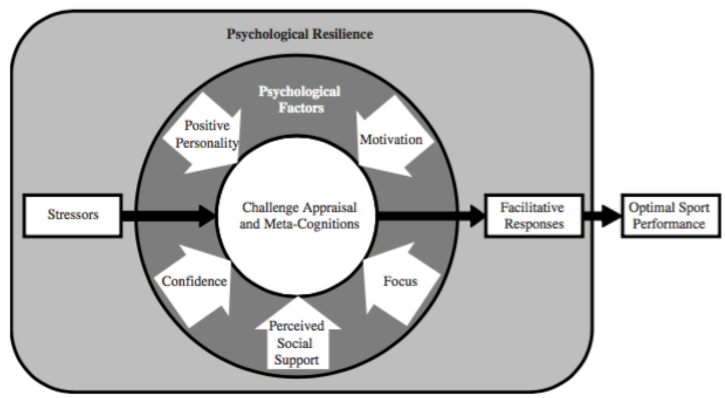
Acutely, alcohol consumption can influence motor skills, hydration status, aerobic performance as well as aspects of recovery (Siekaniec, 2017). Chronically, alcohol consumption can lead to difficulties in managing body composition, nutritional deficiencies, depressed immune function, and an increased risk of injury and/or prolonged healing time during return to snow processes (Siekaniec, 2017). Alcohol ingestion following training or competition can increase urine output, resulting in dehydration. Athletes should be advised to make it a point to replace glycogen, water loss, and ingest optimal protein so as not to inhibit muscle protein synthesis following intense bouts of training and competition and before consuming alcohol. Beyond the immediate implications of alcohol consumption, athletes who consume alcohol are likely to experience reduced sleep quality and quantity. Finally, in recreationally trained athletes, research has found that high doses of alcohol intake after resistance exercise increased cortisol levels and decreased the testosterone-to-cortisol ratio, which can interfere with the adaptive process of long-term resistance training (Siekaniec, 2017). In short, best practices appear to be to instruct the athlete to adhere to standard nutritional recommendations for recovery prior to, during, and after consuming alcohol.

SECTION #10

PSYCHOLOGY

For most athletes who participate in the sport of mogul skiing, the Olympic Games represent the pinnacle of sporting achievement. Winning and Olympic gold medal is typically recognized as the ultimate accolade of a successful athletic career and arguably the most demanding challenge an athlete can pursue (Arnold & Sarkar, 2015). The intense scrutiny, magnitude, and globalization of such an event brings with it enormous pressure and only those who can manage the stress that accompanies the sport at this level will be successful.

The stressors that athletes are sure to encounter upon arrival to US Ski and Snowboard include but are not limited to: 1) Team/Olympic/WSC selection, 2) Competition of a different nature (e.g. World Cup, International, Olympic Games, World Ski Championships), 3) Personal beliefs and values (e.g. self-belief, self-value, personal affirmations) , 4) Pressure due to rarity of event(s), 4) External distractions (e.g. social media, family, sponsors, fans), 5) Performance considerations (e.g. health, injuries, lack of performance), 6) Coach-athlete considerations (e.g. US national coaches, club coaches, informal consultants), 7) Motivation (e.g. sport training, physical preparation, sport psychology, recovery and rehabilitation, nutrition) , 8) Financial (e.g. athlete funding, sponsorship, employment, donations), 9) Environmental stresses (e.g. extensive travel, nutritional alterations, language barriers, etc.), and 10) Planning for the future (e.g. education, employment, internships, family/relationships). It is important to note that these pressures do not operate independently but rather form complex relationships that can derail an athletes career and/or season.



Above: Graphic representation of psychological factors that influence optimal sport performance (Sarkar & Fletcher, 2014)

Psychological Resilience in Mogul Skiers

It is evident that several stressors have the potential to impact the athlete from both a personal and performance standpoint. Sarkar and Fletcher (2014) have identified five main families of psychological factors that protect the best athletes from the potential negative effects of stressors. These include: 1) positive personality, 2) motivation, 3) confidence, 4) focus, and 5) perceived social support.

Personality traits have been defined as “the relatively enduring patterns of thoughts, feelings, and behaviors that reflect the tendency to respond in certain ways under certain circumstances” (Arnold & Sarkar, 2015, p. 6). It has been found that Olympic gold medalists possessed numerous positive personality characteristics, which influenced the resilience-related mechanisms of challenge appraisal and meta-cognition. The main personality traits that have been found to have a desirable impact on athletes' reactions and responses are adaptive perfectionism, optimism, competiveness, hope and proactivity. Each trait has been defined below (Arnold & Sarkar, 2015):

- Adaptive perfectionism is a healthy type of perfectionism that is characterized by having high personal standards and striving for excellence but, at the same time, having little concern for mistakes and doubts about actions.
- Optimism has been defined in two main ways: as a trait-like expectancy for successful outcomes and as an approach to explaining positive and negative events.
- Competiveness has been described as the desire to win in interpersonal situations.
- Hope is defined as a cognitive set that is based on a reciprocally derived sense of successful goal-directed determination and a planning of ways to meet goals.
- Proactivity has been defined as a dispositional construct that identities differences among people in the extent to which they act to influence their environments.

Learning from Olympic Champions

The topic of motivation addresses the "what" and "why" of human behavior, and concerns "energy, direction, persistence and equifinality – all aspects of activation and intention" (Arnold & Sarkar, 2015, p. 7). Optimal levels of motivation are consistently reported as a required psychological attribute for withstanding stress and pressure in competitive sport. It has been found that Olympic champions had multiple motives for competing at the highest level including "being the best that you can be", social recognition, passion for the sport, achieving incremental approach goals, demonstrating competence and proving their worth to others. Particularly important in the context of psychological resilience, Olympic gold medalists consciously valued and judged external demands as important and therefore actively chose to perform in challenging sport environments.

In addition to motivational factors Olympic champion also consistently display the following traits (Arnold & Sarkar, 2015):

- *Confidence.* Confidence has been identified as a positive influence for withstanding stress and pressure in competitive sport. Various sources of confidence are salient to the world's best athletes, including multi-faceted preparation, performance accomplishments, self-awareness, social support, competitive advantage, visualization, trust, coaching and teammates.
- *Focus.* Focus refers to a person's ability to exert deliberate mental effort on what is most important in any given situation. Specifically, Olympic champions were able to focus on relevant cues in the environment, maintain focus over long time periods, remain aware of the situation around them and alter the scope of their attention as demanded by the situation.
- *Perceived Social Support*. Perceived social support refers to one's potential access to social support and is an athlete's subjective judgment that friends, teammates, and coaches would help if needed. It has been found that Olympic champions were protected from the pressures of elite sport by perceiving that high-quality social support was available to them, including support from family, coaches, teammates and support staff.

Social Media

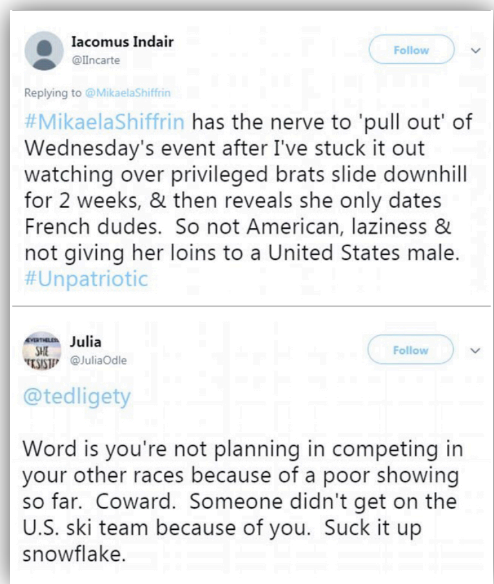
The use of social media platforms present an unavoidable part of the experience of the US Ski and Snowboard team athlete. There are several factors to consider when discussing this topic. At the forefront is the purpose of social media in the lives of the athlete. Athletes use social media in the team environment to achieve a few means, these include but are not limited to: 1) maintaining contact with family and friends while on the road, 2) communication with followers or fans, 3) accessing information, 4) promotion of sponsors or sponsorship obligations, and 5) promotion of their own personal brand (Browning & Sanderson, 2012).

While there are several benefits that come with the use of social media there are also many pitfalls athletes must avoid. At the top of that list is the potential for negative media attention. “Inappropriate tweets generate considerable media attention…” and athletes tend to be lightning rods for sports media and fans to criticize every word or performance that is shared (Browning & Sanderson, 2012, p. 505). Our very own Lindsay Vonn is a great example, after she shared her opinions regarding the current political landscape preceding the 2018 Olympic games in Pyeongchang, South Korea.

While communication with followers and fans helps develop an athletes personal brand, it also opens the doors for criticism of performance, inflammatory language, or other attacks (Browning & Sanderson, 2012). Consider our own Ted Ligety and Mikaela Shiffrin who were recently belittled on the social media site Twitter for their lack of participation in a 2018 FIS World Cup event in Solden, Austria. See examples of this social back lash in the image below/right.

Finally, the ability to access information also gives the athlete the ability to access misinformation. As observed by the author, athletes routinely scour social media to observe the training of their competitors or find better venues to train; the proverbial “the grass is always greener on the other side”. Unfortunately, what is shared on social media doesn’t always ring true. In the search for the competitive edge athletes lose focus on their processes and those constrains in which they have direct control.

The prominence of social media corresponds to a need for sports organizations to proactively assist athletes in its use. Browning and Sanderson (2012), suggest a few options for helping athletes manage this aspect of their careers; they are as follows, in order of most invasive to least invasive: 1) prohibition – either permanently or using blackout periods, 2) Surveillance using social media monitoring platforms, and/or 3) education. Current practices at US Ski and Snowboard revolve around surveillance and education.



Psychosocial Factors in Injury Rehabilitation

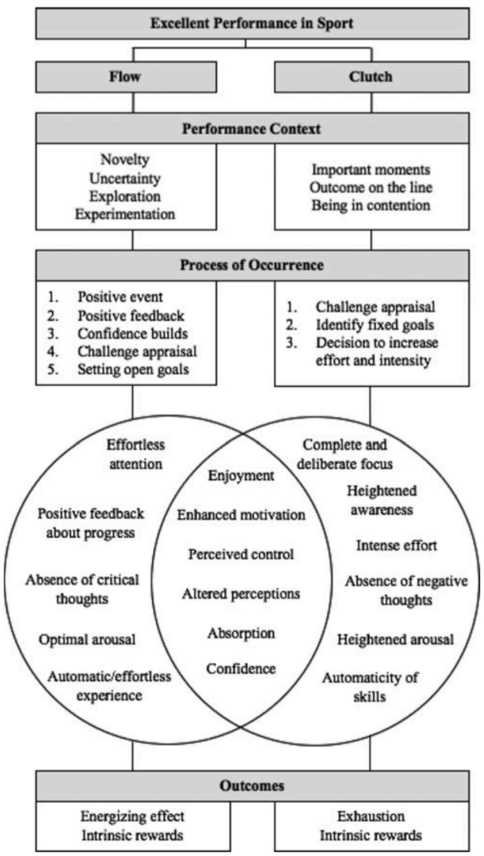
Injury is an emotionally disruptive experience for anyone, but perhaps more so for athletes, especially those for whom sport is central to lifestyle and personal identity (Podlog, Heil, & Schulte, 2014). Research on psychological factors has found that cognitive appraisals, emotional reactions, and behavioral responses to injury influence the quality and nature of athletes’ rehabilitation.

Podlog et al. (2014), identify a range of thoughts that influence athletes’ emotions and behavior in rehabilitative settings, including attribution for injury occurrence, self-perceptions following injury, cognitively based coping strategies, and perceived injury benefits. Athletes’ emotional reactions to injury include feelings of loss, denial, frustration, anger and depression. Surprisingly, not all emotions an athlete experiences are negative. Positive emotions such as a happiness, relief, and excitement have been reported as well (Podlog, Heil, & Schulte, 2014).

Once the rehabilitative process is underway emotions typically fluctuate in response to rehabilitation progress and/or setbacks. More broadly, emotional states typically move from negative to positive as the athlete progress through their rehabilitation and a return to competition draws near (Podlog, Heil, & Schulte, 2014).

Adherence to the rehabilitative process has a been identified as a critical component success by Podlog et al. (2014). Personal factors linked to adherence include pain tolerance, self-motivation, tough-mindedness, perceived injury severity, internal health locus of control, self-efficacy, and self-esteem have all been positively associated with rehabilitation adherence, whereas mood disturbance and fear of re-injury are negatively associated.

Demographic factors such as age have also been found to influence rehabilitation adherence. Older patients were more adherent when they were self-motivated and perceived high levels of social support, whereas younger patients were more adherent when they were highly invested in the athlete role as a source of self-worth. Adherence has been positively associated with enhanced clinical outcomes such as proprioception, range of motion, joint/ligament stability, muscular strength and endurance, as well as reductions in the subsequent risk of re-injury.



Active coping responses such as use of positive self-talk, imagery, goal setting, and seeking out additional information about injury are also associated with adherence. In addition, situational factors, mostly related to perception of treatment, also predict adherence, including a belief in the efficacy of the treatment, information about rehabilitation, the clinical environment, value of rehabilitation to the athlete, and hours a week of sport involvement (Podlog, Heil, & Schulte, 2014).

Flow and Clutch

Given the nature of the Olympic winter games and the infrequency of their occurrence it is important to understand what psychological circumstances might surround the very best performances on the very biggest days. Coaches and practitioners would be wise to recognize the experience of the athlete and employ the proper strategies to walk the athlete to an optimal state of psychological readiness. These strategies can be seen in the flow chart at the left.

Of great consideration to the practitioner, a distinction has been made between the flow state and the clutch performance. Clutch states are characterized by complete and deliberate focus on the task, whereas flow is characterized by effortless attention; clutch states involve heightened awareness of the situation and its demands, whereas flow involves positive feedback and feelings that "everything is going to plan"; clutch states involve intense effort, in contrast to flow, which is characterized by an effortless, automatic experience. Common to both states, however, are the experiences of enjoyment, enhanced motivation, perceived control, altered perceptions of time and the environment, absorption, and confidence (Swann, 2018).

Flow is commonly defined as an intrinsically rewarding, harmonious psychological state involving intense focus and absorption in a specific activity, with a sense of everything coming together or clicking into place, even in challenging situations (Swann, 2018). Flow has been associated with exceptional performance, as well as factors underlying long-term participation in sport and exercise, including engagement, enjoyment, and motivation.

A systematic review of flow in elite sport highlighted 12 facilitators of flow, such as effective preparation, positive thoughts and emotions, optimal environmental and situational conditions, positive feedback, and optimal motivation and arousal (Swann, 2018). Although these factors may facilitate flow, it remains unclear if these are simply associations rather than causal mechanisms.

Clutch states appear to be more constructive during pressure phases when an outcome is on the line, whereas flow states appear to be useful in contexts of exploration, discovery, and experimentation and it of vital importance the practitioner and coach understand the difference. By understanding the mechanisms underlying the occurrence of flow and clutch athletes, coaches, and practitioners may be better able to create interventions and practices to induce and prolong them.

SECTION #11

COACHES OBSERVATIONS

The Cost of Doing Business

The cost of doing business in the sport of mogul skiing is quite severe and is perhaps one of the most contentious points at US Ski and Snowboard. Arguments about athlete funding materialize at nearly every team meeting even to the extent where mogul athletes, with the support of the organization, conducted their own private fundraising event. Currently, there a total of 6 funded athletes (40%) on the US Freestyle Moguls Team (Bullock, The Financial Cost of Mogul Skiing on the World Cup, 2018). During the 2018-2019 season, each funded athlete has both the preparatory and competitive financial costs subsidized by US Ski and Snowboard. The total cost to subsidize the 2018-2019 preparatory period is $21,027.05 (Bullock, The Financial Cost of Mogul Skiing on the World Cup, 2018).

It is important for the coach, practitioner, and athlete to understand the relative cost of doing business and how much each training opportunity costs; thus, providing a monetary value to each training event. As each athlete ultimately completes a different quantity of work the author has provided a range of cost using the highest training quantity and the lowest training quantity from each camp. Briefly, each training event costs the athlete (or US Ski and Snowboard for those funded) between $25.58 and $43.81 per training event (Bullock, The Financial Cost of Mogul Skiing on the World Cup, 2018). In other words, each time the athlete completes a jump, drill, section, or attempts a top to bottom he or she can expect to pay somewhere in the range of $25.58 and $43.81 for that attempt.

The image below provides the detail of each training camp from the 2018-2019 preparatory period, the costs associated with it, and the cost per training attempt for both the highest volume and lowest volume completed at the camp (Bullock, The Financial Cost of Mogul Skiing on the World Cup, 2018).

	Squaw	Hood #1	Hood #2	Hood #3	Zermatt	Wolf Creek	Sum of Prep
Total Cost (All Funded Athletes)	$13,090.36	$13,082.80	$18,947.19	$14,313.97	$56,267.31	$10,460.68	$126,162.31
Total Cost (Per Funded Athlete)	$2,181.73	$2,180.47	$3,157.87	$2,385.66	$9,377.89	$1,743.45	$21,027.05

	Training Events	Total Volume						
ROI (High Volume)	Jumps	0	106	121	99	162	58	**546**
	Drills/Flats	22	0	11	19	35	12	**77**
	Sections	45	0	26	19	39	50	**134**
	Attemped T to B Runs	0	0	0	0	65	0	**65**
	Total Training Events	**67**	**106**	**158**	**137**	**301**	**120**	**822**
	Cost Per Training Event	***$32.56***	***$20.57***	***$19.99***	***$17.41***	***$31.16***	***$14.53***	***$25.58***

	Training Events	Total Volume						
ROI (Low Volume)	Jumps	0	69	93	64	91	20	**337**
	Drills/Flats	20	10	9	0	25	4	**48**
	Sections	44	0	22	0	25	20	**67**
	Attempted T to B Runs	0	0	0	0	28	0	**28**
	Total Training Events	64	79	124	64	169	44	480
	Cost Per Training Event	***$34.09***	***$27.60***	***$25.47***	***$37.28***	***$55.49***	***$39.62***	***$43.81***

The monetary cost of doing business is not the only consideration for the coach, practitioner, and athlete. One must also consider the time investment. Team members spend considerable time attending training camps, both domestic and abroad, with the singular purpose of sporting skill development. The table below provides details regarding the total number of minutes spent training at each camp and the approximate number of minutes spent on skill development each day.

Again, as each athlete ultimately completes a different quantity of training, the author has provided a range of time invested using the highest quantity and the lowest quantity from each camp. Briefly, at each training camp the athlete spends between 0.93 and 1.63 minutes training sporting skill development (Bullock, The Time Investment and Return on Investment During Preparation of World Cup Mogul Skiers, 2018). Implications for the athlete are extreme and place the upmost priority on each opportunity he or she is presented.

	Squaw	Hood #1	Hood #2	Hood #3	Zermatt	Wolf Creek	Sum of Prep
Total Number of Days At Camp	9	7	7	7	25	7	62

Time per Jump (s)	4
Time per Drill/Flat (s)	8
Time per Section (s)	14
Time per T to B completed (s)	28

***All times approximate and taken from video.*

	Training Events	Total Volume (Minutes Invested)						
ROI -Minutes (High Volume)	Jumps	0.00	7.07	8.07	6.60	3.87	3.87	**29.47**
	Drills/Flats	2.93	0.00	1.47	2.53	4.67	1.60	**10.27**
	Sections	10.50	0.00	6.07	4.43	9.10	11.67	**31.27**
	Attemped T to B Runs	0	0	0	0	30.33	0	**30.33**
	Total Time Training (min)	**13.43**	**7.07**	**15.60**	**13.57**	**47.97**	**17.13**	**101.33**
	Training Time (minutes/day)	***1.49***	***1.01***	***2.23***	***1.94***	***1.92***	***2.45***	***1.63***

	Training Events	Total Volume (Minutes Invested)						
ROI - Minutes (Low Volume)	Jumps	0.00	4.60	6.20	4.27	6.07	1.33	**22.47**
	Drills/Flats	2.67	1.33	1.20	0.00	3.33	0.53	**6.40**
	Sections	10.27	0.00	5.13	0.00	5.83	4.67	**15.63**
	Attemped T to B Runs	0.00	0.00	0.00	0.00	13.07	0.00	**13.07**
	Total Time Training (min)	12.93	5.93	12.53	4.27	28.30	6.53	57.57
	Training Time (minutes/day)	***1.44***	***0.85***	***1.79***	***0.61***	***1.13***	***0.93***	***0.93***

Weather

The weather presents another unique challenge to the sport and has implications for athlete preparation. The sport of mogul skiing requires specific set of circumstances for training to take place. Foremost, the temperatures proceeding the training camp need ideal for adequate snowfall. Assuming sufficient snowfall and course/training venue construction, upon arrival ideal conditions involve minimal snow/fog/rain to provide the athletes with the necessary visibility to train the course safely. Finally, wind speed need to be minimal (less than 35kph) to operate most uphill transit, especially when in route to a glacier training site (Bullock, The Influence of Weather on World Cup Mogul Skiing Preparation, 2018).

Many training days are lost each year due to inclement weather conditions. The graph at the right shows the number of days (6) lost due to weather during the 2018-2019 preparatory period. A total of 12.3% of all scheduled training days were lost due to weather conditions at the training site or transit to and from the course (Bullock, The Influence of Weather on World Cup Mogul Skiing Preparation, 2018).

Venue	Days Planned	Days Lost	Days Realized
Squaw	7	0	7
Hood #1	6	1	5
Hood #2	6	1	5
Hood #3	6	0	7
Zermatt	18	4	14
Wolf Creek	6	0	6
Total	49	6	43
Percentage Lost: 12.3%			

Given the potential for loss of training (skill development) opportunities, coaches and athletes should attempt to capitalize on each day they are able to train. The moguls coaching staff encourages athletes to pursue each day with purpose and resist the urge to wait or "get to it tomorrow" as that future opportunity is far from guaranteed. A fact of training that should be acknowledged by the coach and strength and conditioning practitioner as this could result in abrupt and unavoidable spikes in training volume and/or intensity during periods of skill development.

Team Sport Culture

The US Freestyle Mogul Team consists of men and women who are both friends and competitors. This presents a unique challenge to the culture of the team as the individuals develop relationships while simultaneously competing for podium position, world rank, Olympic and World Ski Championship participation, and athlete funding. They do all of this while sharing a room, plane, train, bus, car, course, and gym throughout the year. Such close quarters and high stakes make the nature of these relationships very important to the success of both the individual and the team.

Culture is considered one of the most prominent contributors to the success of organizations, especially sport organizations (Cole & Martin, 2018). It is considered by some to be the most important element in ensuring strategic success. It is with this in mind that coaches and practitioners should maintain a conscious understanding of culture to better ensure its influence is strong and positive.

According to Cole and Martin (2018), a team's culture depends on four elements: 1) stability, 2) depth, 3) breath, and 4) integration. Stability is present when the culture and its associated values are constant and hard to change despite personnel turnover. Depth of culture is achieved when it becomes embedded in everything the group does and values influence decisions without conscious implementation. Breath occurs when the culture is present in all a team's functional areas from top to bottom. Finally, integration refers to how well cohesion is achieved between behaviors, values, and rituals.

The creation of a strong culture is a conscious effort and requires six necessary triggers to solicit its establishment; they include:

1) Those who have the most formal and informal influence on team direction and peer behavior must embrace the values of the culture.
2) The values must be reinforced via formal and informal means
3) When in crisis the leaders lean on team values.
4) The leaders must place an emphasis on situations to reinforce the established values.
5) There is a strict selection of members to the team who will embrace the values.
6) The values are reinforced by rewarding the expression of the desired culture.

In terms of team and organizational structure, those with a laterally coordinated structure perform better and have a greater ability to innovate (Cole & Martin, 2018). This premise is supported by current literature as well as the experience of the author. In an investigation of firms with less than 500 staff in England it was observed that those who employed decentralized decision making (lateral coordination), achieved better results from clients (Cole & Martin, 2018). This same sentiment has been echoed in team sports in which Johnson and colleagues (2012) studied the effectiveness of collective leadership in the All Blacks, New Zealand's world renowned rugby team. The All Blacks informal collective leadership model (since formalized) has helped them amass an astounding 85.4% winning percentage between 2004 and 2011. Given the individual nature of mogul skiing it seems logical such a system should be employed.

Many authors in both business and athletic literature identify leadership style as central to the conscious influence of team and organizational culture. Cole and Martin (2018) found through descriptive surveys sports teams preferred a coach who uses transformational leadership. The surveys also revealed that transformational leadership had the strongest influence on culture. This approach is in stark contrast to the alternative, transactional coaching, whereby the leader(s) help team members achieve short term goals with a focus on the athlete's relationship with that goal. Transformational coaching has the underlying goal of assisting the athlete in personal growth; such that the athlete acquires skills that will empower him or her deal with such related issues in the future. Mogul skiing and life on the US Ski and Snowboard team is very transitional. Some athletes may have stints off the team or in the rehabilitative process that limit their contact to coaches and thus, a player transaction is likely to take place. It is the opinion of the author such barriers to transformational leadership should attempt to be overcome through communication and the development of relationships that center around people rather than results.

During the 2018-2019 preparatory period the US Freestyle Mogul Team spent significant time in establishing team values and consequently a culture of shared beliefs and goals. The team values can be seen in the chart below.

US Freestyle Mogul Team Values 2018-2019	
Communication	**Dominant**
We will communicate individually and as a group	We will follow through
We will speak our minds	We will be the most successful mogul team in the world
Grit	We will win the day
We will take ownership	We will strive for mastery
We will learn from our mistakes and successes	**Respect**
We will be tough	We will respect everyone's time
We will be intentional everyday	We will listen to each other with an open mind
Real	**Leadership**
Positive or negative we will be open and honest	We will be ambassadors for the sport and the nation
Trust / Supportive	**Unique**
We will stand up for each other no matter what	We will be coached as individuals and act as a team
	We will create a team that people want to join

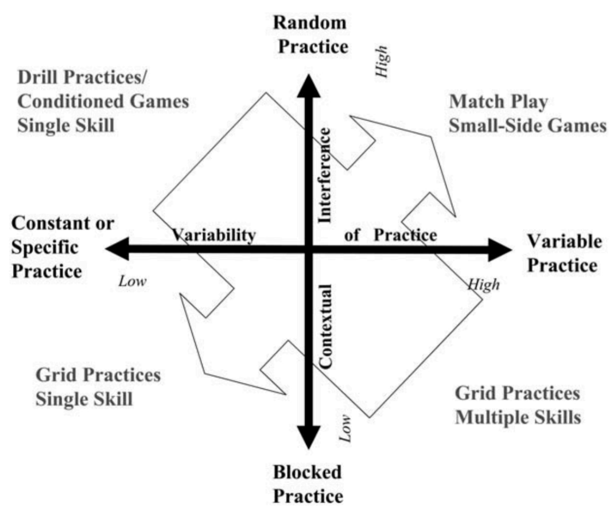
Significant steps have been made, from both an athlete as well as coaching standpoint, to improve organizational structure and leadership style. There are very few mandatory requirements of athletes but rather opportunities for improvement and education are made available. Coaches, in the case of younger athletes, dictate programming. However, in the case of more experienced athletes' coaches act more as consultants in a shared process. From time to time, all athletes need to be challenged, reminded of values, and in response, the coaching staff and practitioner should expect the athlete to rise to meet that challenge.

Skill Development

Athletes tend to spend most of their time attempting to refine and develop technical and behavioral skills whereas much less effort is spent attempting to improve or refine aspects of fitness. Not surprisingly, a significant investment of time and practice is required to reach an elite level of performance. It is believed by many that athletes have a genetic gift for their sport and that those gifts cannot be learned or trained, only inherited. However, while hereditary factors do play a role, an individual's skills are highly modifiable and adaptable to training and every skier will need to practice for many hours to develop and refine their skill set.

When discussing the development of skills, particularly ski and air skill, there are five myths the pervade the process (Williams & Hodges, 2005):

1) *Demonstrations are always effective in conveying information to the learner.* The main reason for using demonstration is to provide the learner with a visual template for the desired movement pattern. Widespread acceptance of demonstration as an essential method of conveying information to the learner should be questioned. Although demonstration usually facilitate the instruction process, they are sometimes no more effective than verbal instruction and, in certain instances, they may hinder the learning and long-term retention of motor skills. Coaches and practitioners would be wise to employ demonstrations using multiple examples and/or developmental examples so as not to constrain the learning process.
2) *Specific, blocked practice of a single skill is essential for skill learning.* Skills can be practiced in a blocked or random manner under constant (specific) or variable conditions. It is traditional for coaches to begin the instruction process with blocked, constant practice of a single skill before progressing to drill practices and then eventually to random, variable practice conditions. The problem with this approach is coaches typically judge their effectiveness by observing players' performance during the training session. The difficulty for coaches is that considerable evidence exists to suggest that several of the interventions using during the instruction process affect performance and learning in different ways. Coaches should be cognizant that variability in movement and context characteristics are essential to develop a more expansive, generalized motor program to cope with a variety of similar but different situations. Finally, and most importantly, an awareness that while specific blocked training is better for performance, variable, random practice is more effective for skill learning.



Above: Image depicting the construct of a practice relative to skill development and performance (Williams & Hodges, 2005).

3) *Augmented feedback from a coach should be frequent, detailed and provided as soon as possible after the skill has been performed.* There are two type of feedback available to the learner. Intrinsic feedback is available as a natural consequence of performing an action as the skier will be able to see, feel, and sometimes hear the consequence of specific movements. Extrinsic feedback can be provided by a coach or teammate immediately following the movement or later using video observation. Coaches need to be aware of how these different sources of feedback work both alone and in conjunction with other instructional techniques. Providing augmented feedback on every trial has a beneficial effect on performance but a detrimental effect on skill learning. Coaches should engage the learner in the problem-solving process and resist the urge to provide feedback on every practice attempt.
4) *Prescriptive coaching is always better for skill acquisition than instructional approaches based on learning by guided discovery.* Prescriptive coaching is often thought of as 'hands-on" or authoritarian; whereby the coach has all the necessary

knowledge and that this information must be passed on to the learner. Evidence suggests an approach which is overly prescriptive results in skills which are less resistant to the effects of psychological stress and more prone to fading over time than skill learnt through guided discovery. Coaches should emphasize learning through guided discovery allowing players to take responsibility for their own development, finding unique solutions to movement problems through exploration and discovery. This more "hands-off" may be more effective in developing skiers who are able to apply their skills in a variety of performance situations. This task does not imply the importance of coaching is diminished, merely the role needs to be redefined so that there is greater awareness of how coaches can shape and guide rather than dictate the learning process.

5) *Game intelligence skills are not amenable to practice and instruction.* Coaches consider that game intelligence improves purely as a result of playing experience and that it is not possible, or at best too difficult, to develop structured training programs to improve these skills. However, empirical evidence exists to indicate the acquisition of game intelligence skills can be mediated through appropriate interventions. A typical approach would be to film from the learner's perspective and identify course conditions or other circumstances thereby underlying effective anticipation.

In addition to the actual structure and content of training coaches should consider the methods in which they choose to cue athletes when trying to alter a motor pattern or solve a motor problem. Interestingly, and in contrast to other variables studied in the motor learning literature, a person's attentional focus often has a similar influence on both immediate performance (i.e., during the practice phase when focus instructions are given) and learning, which reflects a more permanent change in the capability to perform a skill (i.e., after a certain interval and without instructions or reminders) (Wulf, 2013).

Empirical evidence has amassed for the benefits of adopting an external focus on the intended movement effect (e.g., on the ski or jump) relative to an internal focus on body movements. Such a strategy has positive effects desirable traits in the sport of moguls skiing, including balance, accuracy (ability to repeat a task), movement efficiency, muscular activity, maximum force production, speed, and endurance (Wulf, 2013).

Much emphasis has been given to this process by the coaching staff, however, many traditional habits still exist and likely, may never fade. Ratings of perceived performance, as reported daily by athletes, rarely drop below a four (on a 1-7 Likert scale) indicating that performance may never suffer enough to enhance significant skill development. Such strategies will require continued emphasis and a willingness by the athlete to have a difficult day to advance their skillset. It is the experience of the author that making a cognizant change to training structure and content, as well as delivery method, is very difficult and for the time being will require a conscious effort.

SECTION #12

REFERENCES

References

American College of Sports Medicine; American Dietetic Association; Dieticians of Canada. (2000). A Joint Position Statement: Nutrition and Athletic Performance. *Medicine and Science in Sports and Exercise*, 2130-2145.

Arndt, A. (1992). A Three-Dimensional Kinemtatic Analysis of Alpine Skiing in Moguls. *Department of Human Movement Science, University of Wollongang (Australia)*, 1-94.

Arnold, R., & Sarkar, M. (2015). Preparing Athletes and Teams for the Olympic Games: Experiences and Lesson Learned from the World's Best Sport Psychologists. *International Journal of Sport and Exercise Psychology*, 4-20.

Browning, B., & Sanderson, J. (2012). The Positives and Negatives of Twitter: Exploring How Student-Athletes Use Twitter and Respond to Critical Tweets. *International Journal of Sport Communication*, 503-521.

Bullock, J. (2018). *Energy System Demands of Mogul Skiers.* US Ski and Snowboard, High Performance. Park City: Unpublished Data.

Bullock, J. (2018). *Incidence of Injury in United States World Cup Mogul Skiers from 2014-2018.* US Ski and Snowboard, High Performance. Park City: Unpublished.

Bullock, J. (2018). *The Financial Cost of Mogul Skiing on the World Cup.* US Ski and Snowboard, High Performance. Park City: Unpublished.

Bullock, J. (2018). *The Influence of Weather on World Cup Mogul Skiing Preparation.* US Ski and Snowboard, High Performance. Park City: Unpublished.

Bullock, J. (2018). *The Time Investment and Return on Investment During Preparation of World Cup Mogul Skiers.* US Ski and Snowboard, High Performance. Park City: Unpublished.

Cappert, T. (2002, October). Environmental Cold Consideration During Endurance Exercise. *Strength and Conditioning Journal*, 48-49.

Chapman, R. F., Stray-Gundersen, J., & Levine, B. (1998). Individual Variation in Response to Altitude Training. *Journal of Applied Physiology*, 1448-1456.

Chapman, R. F., Stray-Gunderson, J., & Levine, B. (1998). Individual Variation in Response to Atltitude Training. *Journal of Applied Physiology*, 1448-1456.

Cole, J., & Martin, A. (2018). Developing a Winning Sport Team Culture: Organizational Culture in Theory and Practice. *Sport in Society*, 1-19.

Duffield, R., Dawson, B., & Goodman, C. (2004). Energy System Contribution of 100-m and 200-m track running events. *Journal of Science and Medicine in Sport*, 302-313.

Federation International de Ski. (2013-2014). *FIS Freestyle Skiing Scoring / Judging Handbook.* Thunersee, Switzerland: Federation International De Ski.

Federation International de Ski. (2017, 10 1). *FIS Freestyle Mogul Course Specifications.* Retrieved 2017, from FIS Website: http://wiki.fis-ski.com/images/FIS_Mogul_Specification_MO.pdf

Florenes, T., Heir, S., Nordsletten, L., & Bahr, R. (2010). Injuries Among World Cup Freestyle Skiers. *British Journal of Sports Medicine*, 803-808. Retrieved from Norwegian School of Sport Scientes: brage.bibsys.no/nih

Fulco, C., Rock, P., & Cymerman, A. (1998). Maximal and Submaximal Exercise Performance at Altitude. *Aviation, Space, and Environmental Medicine*, 793-801.

Gabbett, T. (2016). The Training Injury Prevention Paradox: Should Athletes be Training Smarter and Harder? *British Journal of Sports Medicine*, 273-280.
Hashemi, J., Breighner, R., Chandrashekar, N., Hardy, D., Chaudhari, A., Shultz, S., . . . Beynnon, B. (2010). Hip Extension, Knee Flexion Paradox: A New Mechanism for Non-Contact ACL Injury. *Journal of Biomechaniscs*, 577-585.
Hautier, C., Wouassi, D., Arsac, L., Bitanga, E., Thiriet, P., & Lacour, J. (1994). Relationships Between Postcompetition Blood Lactate Concentration and Average Running Velocity Over 100-m and 200-m Races. *European Journal of Applied Physiology and Occupational Physiology*, 508-513.
Heir, S., Krosshauk, T., & Ekeland, A. (2003). The Prevelance fo Previous Serious Knee Injuries in Freestyle World Championshp Skiers. *Skiiing Trauma and Safety*, 1440.
Ikegami, Y., Sakurai, S., Okamoto, A., Ikegami, H., Andou, Y., & Sodeyama, H. (1994). Biomechanical Analysis of Body Movement During Skiing Over Bumps. *Journal of Applied Physiology*, 100-110.
Johnson, R., Ettlinger, C., & Shealy, J. (2005). Injury Trends and Risk Factors invovling ACL Injuries in Alpine Skiing. *Knee Surgery, Sport Traumatology, Arthrosopy, 14*, 101.
Johnson, T., & al, e. (2012). A Core Value of Pride in Winning: The All Blacks' Team Cultue and Legacy. *International Journal of Sport and Society*, 1-14.
Kurpiers, N. (1994). Dynamics of Freestyle Skiing. *University of Auckland*.
Kurpiers, N., & McAlpine, P. (2009). Perspectives for Comprehensive Biomehanical Analyses of Mogul Skiing. *Research in Sports Medicine*, 231-244.
McIntyre, J. (1963). Skiing Injuries. *Canadian Medical Association Journal*, 602-605.
Meir, R. (2002). Managing Transmeridian Travel: Guidelins for Minimizing the Negative Impact of International Travel on Performance . *Strength and Conditioning Journal*, 28-34.
Meyer, N., Manore, M., & Helle, C. (2011). Nutrition for Winter Sports. *Journal of Sport Sciences*, 127-136.
Mike, J., Kerksick, C., & Kravitz, L. (2016). How To Incorporate Eccentric Training Into a Resistance Training Program. *Strength and Conditioning Journal*, 5-17.
Naejie, R. (2010). Physiological Adaptation of the Cardiovascular System at High Altitude. *Progress in Cardiovascular Diseases - Journal*, 456-466.
Pettitt, R., Symons, D., Eisenman, P., Taylor, J., & White, A. (2005). Repetitive Eccentric Strain at Long Muscle Length Evokes the Repeated Bout Effect. *Journal of Strength and Conditioning Research*, 918-924.
Podlog, L., Heil, J., & Schulte, S. (2014). Psychosocial Factors in Sports Injury Rehabilitation and Return to Play. *Physical Medicine and Rehabilitation Clinics of North America*, 915-930.
Robson-Ansley, P., Gleeson, M., & Ansley, L. (2013). Fatigue Management in Preparation of Olympic Athletes. *Track and Field*, 37-41.
Russell, K., Christie, J., & Hagel, B. (2010). The Effect of Helmets on the Risk of Head and Neck Injuries Among Skiers and Snowboarders: A Meta-Analysis. *Canadian Medical Association Journal*, 333-340.
Sands, W. (2017). The Quantified Mogul Skier. *Unpublished Data: US Ski and Snowboard*, 1-59.
Sands, W. (2018, June 7). Managing Jet Lag. *Presentation Given At US Ski and Snowboard Center of Excellence*. Park City, UT, USA: Unpublished.
Sands, W., & Bullock, J. (2018). *Acclerometry of Mogul Skiers.* US Ski and Snowboard, High Performance. Park City: Unpublished Data.
Sands, W., & Bullock, J. (2018). *Biomechanics of Mogul Skiers.* US Ski and Snowboard, High Performance. Park City: Unpublished Data.
Sands, W., & Bullock, J. (2018). *EMG of Mogul Skiers.* US Ski and Snowboard, High Performance. Park City: Unpublished Data.
Sands, W., & Bullock, J. (2018). *Energy System Demands of Mogul Skiers.* US Ski and Snowboard, High Performance. Park City: Unpublished Data.
Sands, W., & Bullock, J. (2018). *Muscle Oxygen Saturation in Mogul Skiers.* US Ski and Snowboard, High Performance. Park City: Unpublished.
Sands, W., & Bullock, J. (2019). *Analysis of Single Mogul Start List Order.* Park City: Unpublished Data.

Sands, W., & Bullock, J. (2019). *Moguls Uniform Study.* US Ski and Snowboard, High Performance. Park City: Unpublished.

Sarkar, M., & Fletcher, D. (2014). Psychological Resilience in Sport Performers: A Reveiw of Stressors and Protective Factors. *Journal of Sport Sciences*, 37-41.

Schmitt, K.-U., Liechti, B., Michel, F., Sampfli, R., & Bruhwiler, P. (2010). Are Current Back Protectors Suitable to Prevent Spinal Injuries in Recreational Snowboarders. *British Journal of Sports Medicine* , 822-826.

Sheppard, J., Hobson, S., Barker, M., Taylor, K., Chapman, D., McGuigan, M., & Newton, R. (2008). The Effect of Training with Accentuated Eccentric Load Counter-Movement Jumps on Strength and Power Characteristics of High-Performance Volleyball Players. *International Journal of Sport Science and Coaching*, 355-365.

Siekaniec, C. (2017). The Effects of Alcohol on Performance. *NSCA Coach*, 1-4.

Swann, C. (2018). A Review of Scientific Progress in Flow in Sport and Exercise: Normal Science, Crisis, and a Progressive Shift. *Journal of Applied Sport Psychology*, 249-271.

Thoreson, O., Kovac, P., Sward, A., Agnvall, C., Todd, C., & Baranto, A. (2017). Back Pain and MRI Changes in Thoraco-Lumbar Spine of Young Elite Mogul Skiers. *Scandavian Journal of Medicine and Science in Sports*, 983-989.

Tipton, K., Jeukendrup, A., & Hespel, P. (2007). Nutrition for the Sprinter. *Journal of Sports Sciences*, S5-S15.

US Ski and Snowboard. (2017, October 1). Longitudinal Performance Data. *Freestyle Mogul Skiing Performance Data*. Unpublished Data.

van Hall, G., Calbet, A., Sondergaard, H., & Saltin, B. (2001). The re-establishement of normal blood lactate response to exercise in humans after prolonged acclimatization to altitude. *The Journal of Physiology*, 963-975.

Williams, B., Clarke, R., Aspe, R., Cole, M., & Hughes, J. (2017). Managing Performance Through Periods of Travel. *Strength and Conditioning Journal*, 22-29.

Williams, M., & Hodges, N. (2005). Practice, Instruction, and Skill Acquisition in Soccer: Challenging Tradition. *Journal of Sport Sciences*, 1-15.

Wing, C. (2018). Monitoring Athlete Load: Data Collection Methods and Practical Recommendations. *Strength and Conditioning Journal*, 26-39.

Wulf, G. (2013). Attentional Focus and Motor Learning: A Review of 15 Years. *International Review of Sport and Exercise Psychology*, 77-104.

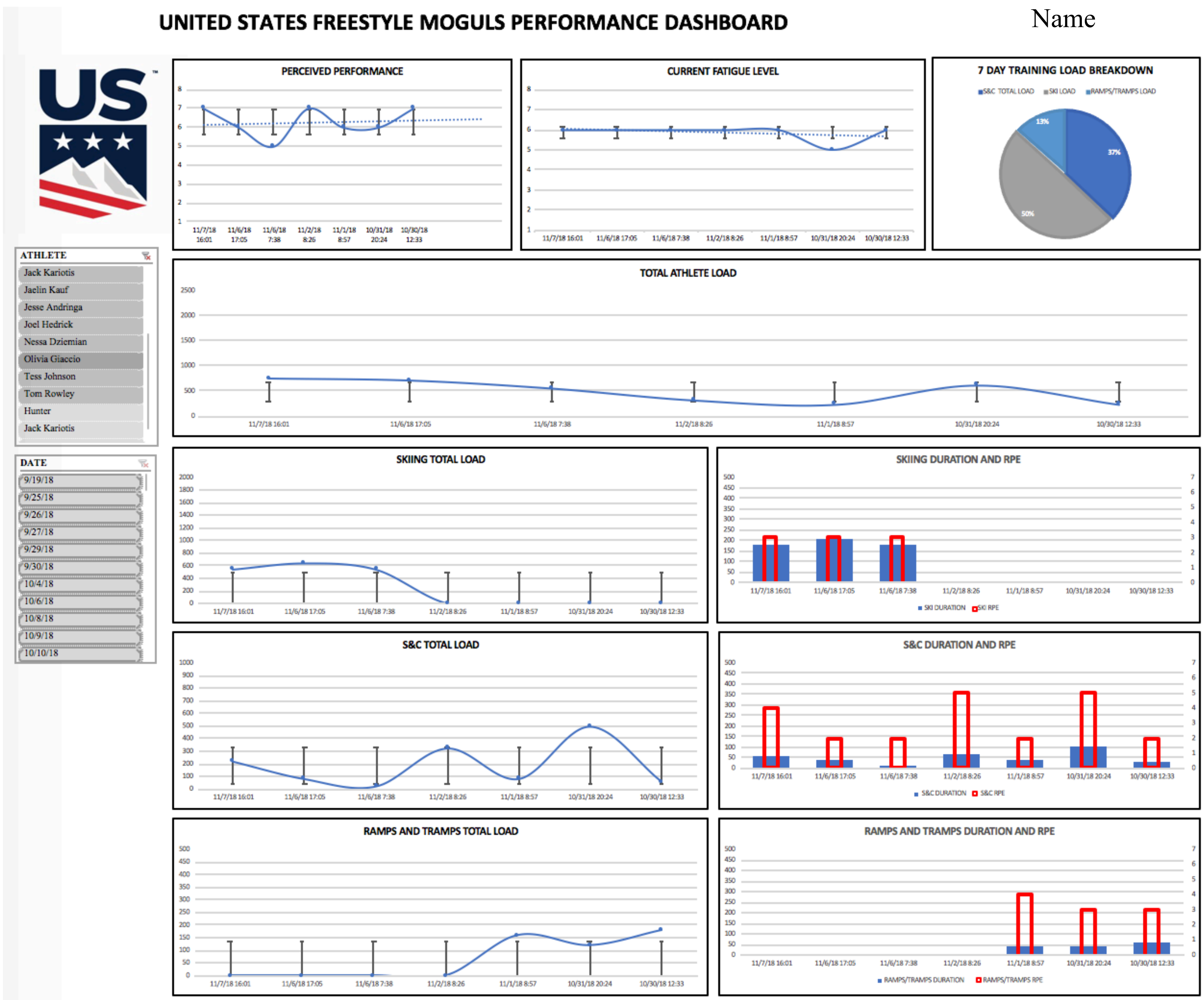
Young, W., & Behm, D. (2002). Should Static Stretching Be Used During a Warm-Up for Strength and Power Activities. *Strength and Conditioning Journal*, 33-37.

SECTION #12

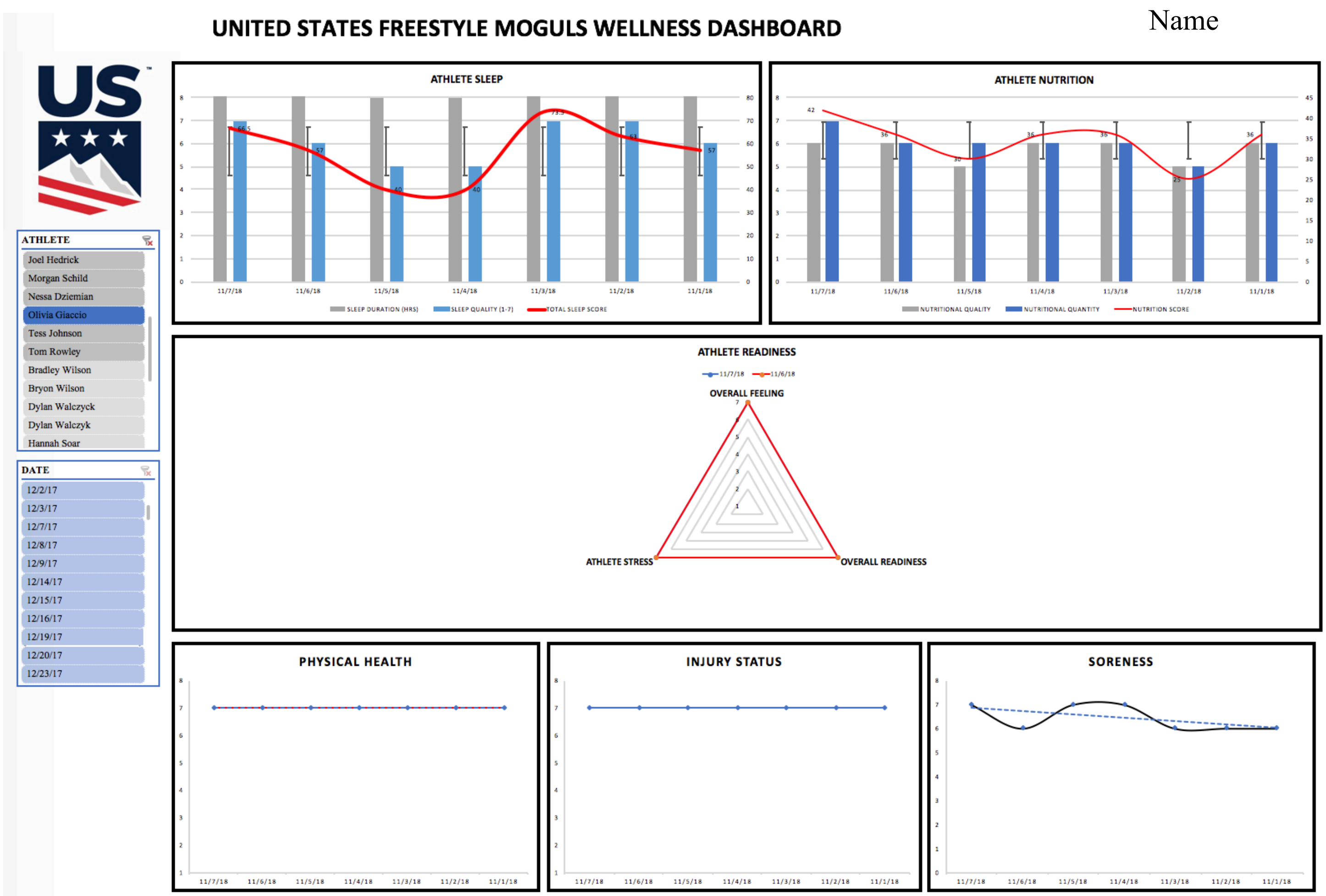
APPENDICES

Appendices

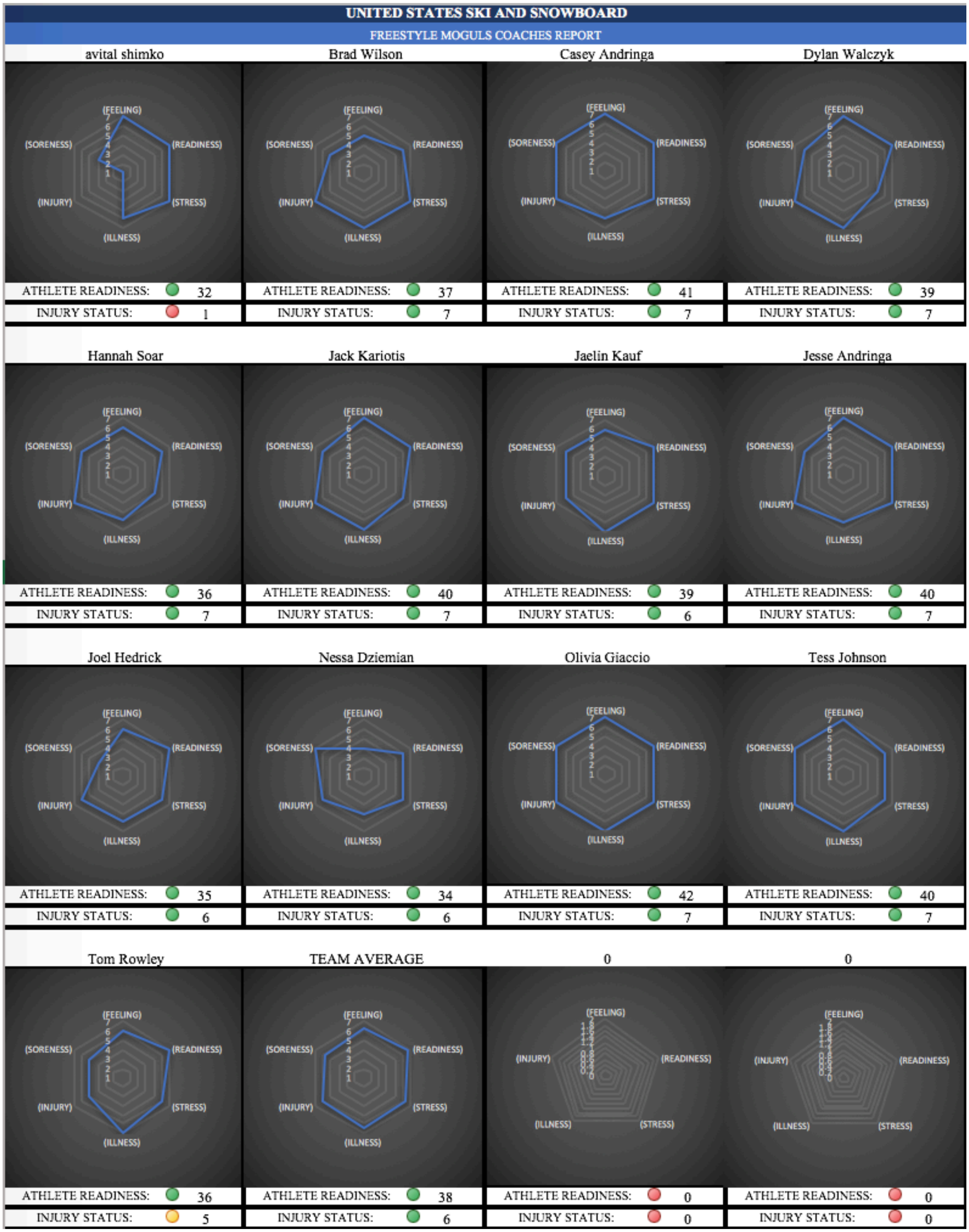
Appendix A – Performance Monitoring (External)



Appendix B – Wellness Monitoring (External)



Appendix C – Sample Daily Sport Coaches Report



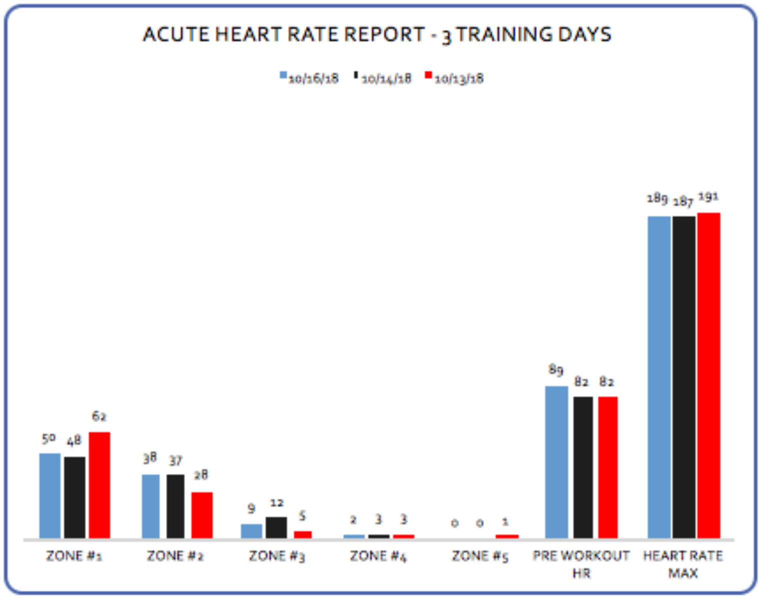
UNITED STATES SKI AND SNOWBOARD

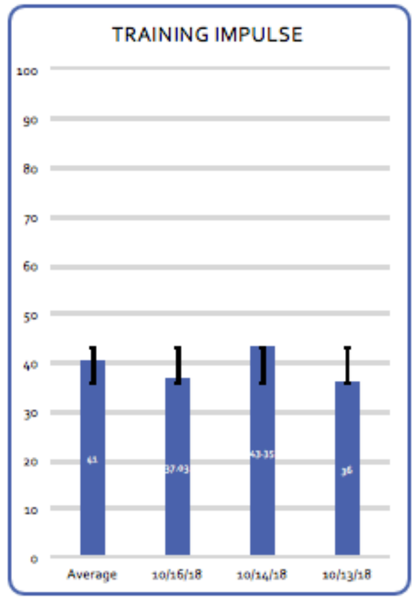
FREESTYLE MOGULS COACHES REPORT

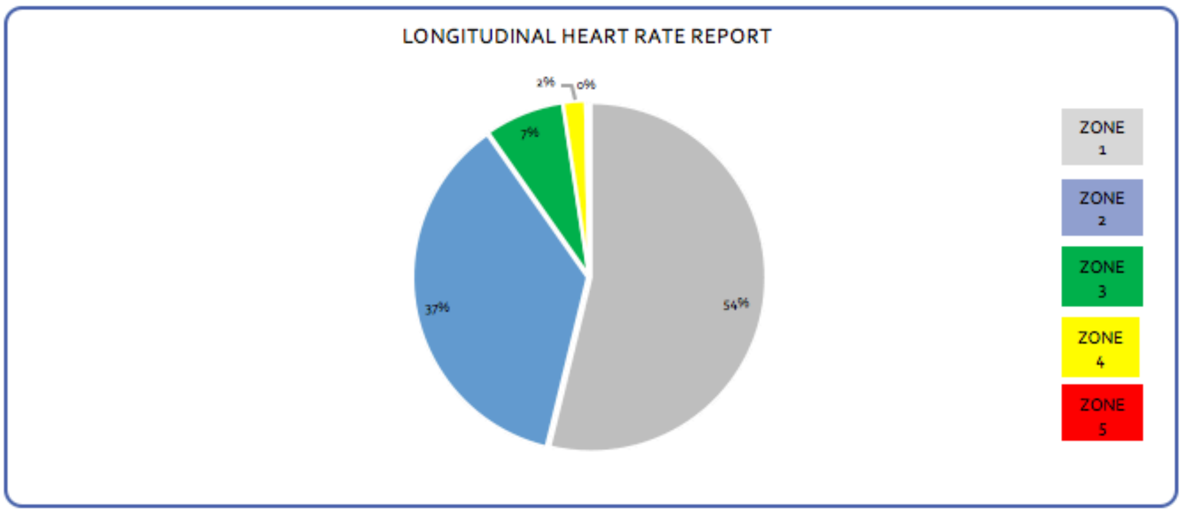
Athlete	ATHLETE READINESS:	INJURY STATUS:
avital shimko	32	1
Brad Wilson	37	7
Casey Andringa	41	7
Dylan Walczyk	39	7
Hannah Soar	36	7
Jack Kariotis	40	7
Jaelin Kauf	39	6
Jesse Andringa	40	7
Joel Hedrick	35	6
Nessa Dziemian	34	6
Olivia Giaccio	42	7
Tess Johnson	40	7
Tom Rowley	36	5
TEAM AVERAGE	38	6
0	0	0
0	0	0

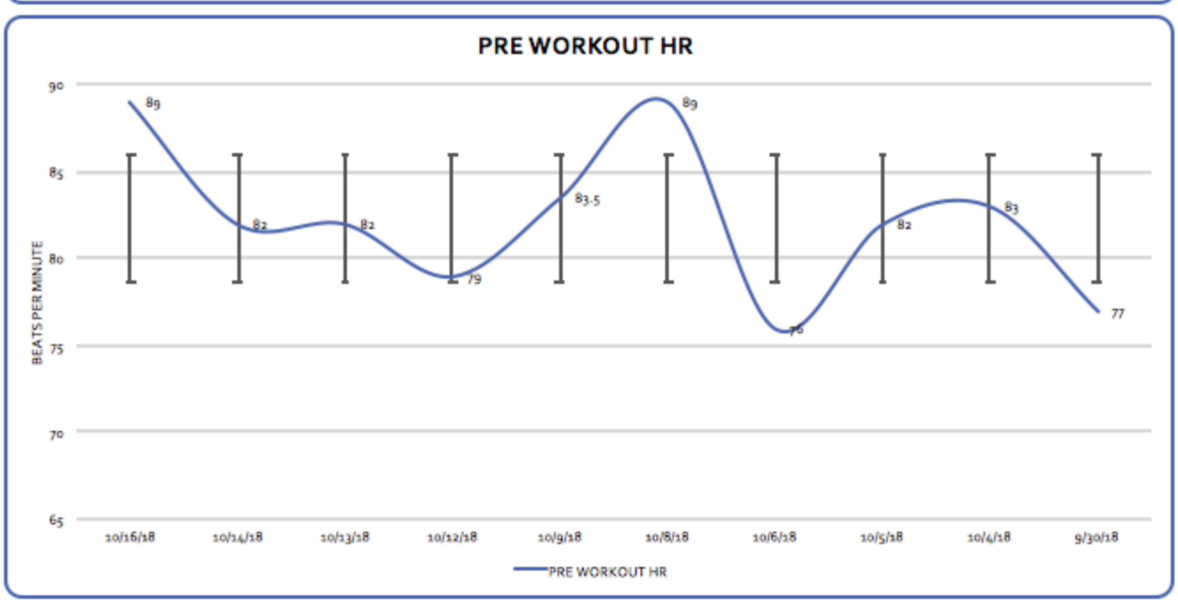
Appendix D – Heart Rate Monitoring (Internal)

Name

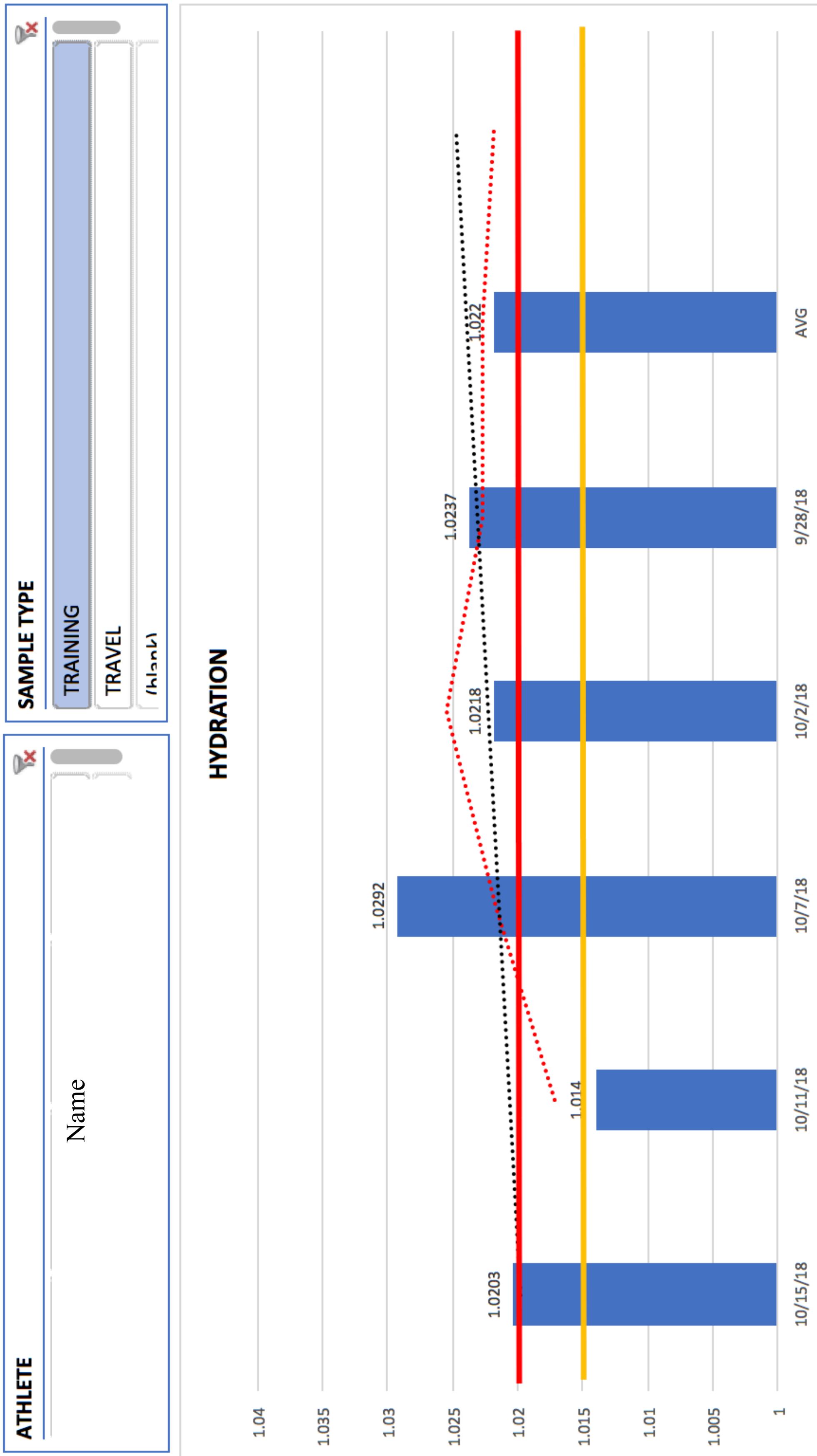








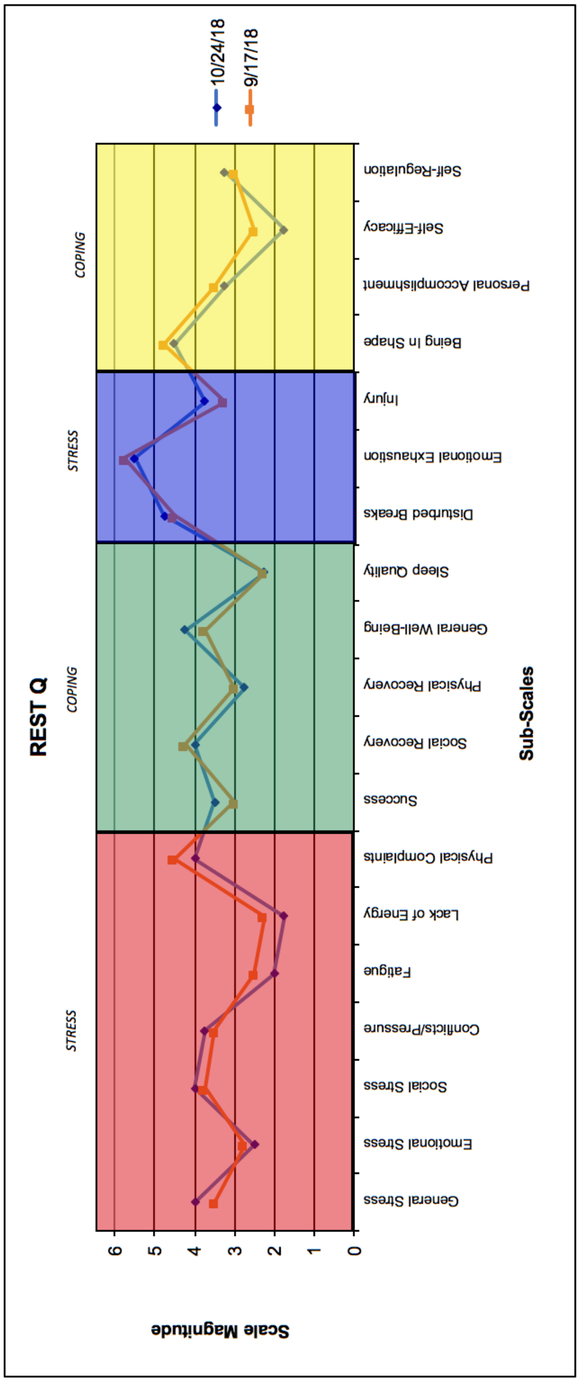
Appendix E – Hydration Monitoring



Appendix F – RESTQ

US SKI AND SNOWBOARD

Name



NAME:

US SKI AND SNOWBOARD: FREESTYLE MOGULS

Year: 2018-2019

KEY	ON SNOW CAMP	OMPETITION TRAININ	TRAVEL	COMPETITION	TRAINING AT THE COE	TESTING	THLETES COACHING AT CAMP!

	MONTH	APRIL		MAY				JUNE				JULY					AUGUST				SEPTEMBER				OCTOBER					NOVEMBER				DECEMBER					JANUARY				FEBRUARY				MARCH				APRIL		
CALENDAR	MONDAY	23	30	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	3	10	17	24	31	7	14	21	28	4	11	18	25	4	11	18	25	1	8	15
	TUESDAY	24	1	8	15	22	29	5	12	19	26	3	10	17	24	31	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	5	12	19	26	5	12	19	26	2	9	16
	WEDNESDAY	25	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	5	12	19	26	3	10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	6	13	20	27	6	13	20	27	3	10	17
	THURSDAY	26	3	10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	7	14	21	28	4	11	18
	FRIDAY	27	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	1	8	15	22	1	8	15	22	29	5	12	19
	SATURDAY	28	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	2	9	16	23	2	9	16	23	30	6	13	20
	SUNDAY	29	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	3	10	17	24	3	10	17	24	31	7	14	21
	WEEKS REMAINING	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	0	3	2	1	0	0	0	1	0	1	0	0	0	34	33	32	31	30	29
SCHEDULE	ON SNOW																																																				
	RAMP CAMP																																																				
	TESTING/DELOAD																																																				
	FIS WORLD CUP SCHEDULE																																	RUKA - MO	CHINA - MO/DM				CALGARY - MO	PLACID - MO/DM	TREMB - MO		DV/WSC - MO/DM		JAPAN - MO/DM	KAZ - MO	WVV - MO/DM						
PERIODIZATION	Macrocycle	US SKI AND SNOWBOARD: FREESTYLE MOGULS - YEAR 1/4 QUADRENNIAL PLAN																																																			
	Training phase	POST		OFF SEASON												PRE SEASON															IN SEASON																		POST SEASON				
	Training subphase	REST		GENERAL PHYSICAL PREPARATION												SPECIFIC PHYSICAL PREPARATION															ACCENTUATION / AUGMENTATION / SYMMETRY																		ACTIVE REST				
	Mesocycle	REST		ACCUMULATION -ECC				ACCUMULATION - ISO				ACCUMULATION - CON				TRANSMUTATION				ACCUMULATION - SM. ECC				TRANSMUTATION			ACC	TRANSMUTATION			REALIZATION					ACC	TRANSMUTAION					REALIZATION		ACC	REALIZATION			ACC	ACTIVE REST				
	Microcycle	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
	ESD	Z1		Z2, Z3, Z1			Z1	Z3, Z4, Z1			Z1	Z3, Z4, Z2			Z1	Z2, Z5, Z4			Z1	Z3 , Z4, Z1			Z1	Z2, Z5, Z4			Z4	Z2, Z5, Z4			Z1, Z2																	Z4	Z2, Z3, Z1				
	Plyometric Training	NONE						BILAT SR		UNILAT SR		BILAT SR		UNLAT SR		BI LAT MR				UNI LAT MR AND SR ALT DROP				UNI LAT SR			NONE	UNI/BI LAT MR			UNI / BI LAT MR & SR																	NONE	BI LAT SR				
	S&C Sessions/Day	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1
	S&C Frequency/ Week	3	1-2	1-2	1-2	3	1-2	1-2	1-2	3	3	3	3	1-3	1-2	1-2	3	3	1-2	3	3	1-3	1-3	1-2	1-2	1-2	1-2	3	3	1-2	1-2	1-2	1-2	1-2	1-2	2	2	1-2	1-2	1-2	1-2	1	0-1	2	1-2	1-2	0-1	3	0	0	2	2	2
	Volume	7	6	10	10	4	30	12	8	4	30	10	10	4	30	15	18	10	30	3	3	2	30	15	18	10	30	15	18	10	5	7	3	5	7	10	15	18	10	15	18	5	7	10	5	7	3	10	7	8	6	10	6
	Intensity	75	77	85	82.5	87.5	50	85	82.5	87.5	50	85	82.5	87.5	50	65	62	68	50	90	95	102	50	65	62	68	50	65	62	68	37	35	40	37	35	85	65	62	68	65	62	40	35	85	37	35	40	85	75	72	77	70	80

GRAPHIC REPRESENTATION

Volume / Intensity Graphic Representation