CCMBM

UCSF Department of Physical Therapy and Rehabilitation Science

UCSF Health Human Performance Center

IMAGING CORE WORKSHOP:
DEMYSTIFYING CLINICAL BIOMECHANICS

WHEN: WED, JAN 17th, 9:00-11:00am

WHERE: UCSF Orthopaedic Institute, 1500 Owens, Suite 110

Join the CCMBM and the Department of Physical Therapy and Rehabilitation Science for an overview of clinical biomechanics best practices featuring experts from the **UCSF Human Performance Center**. Presenters will discuss:

- *State-of-the-art in motion capture and exercise physiology*
- *How to integrate these methods to elevate your MSK research*

This workshop will include demonstrations and example data, with dedicated time for Q&A. Open to and appropriate for **all** MSK researchers no matter their level of expertise.

Presented by:

Anthony Luke, MD, MPH
Director, UCSF Human Performance Center

Richard Souza, PT, PhD
Director of Research, UCSF Human Performance Center

Brooke Schultz, MS, ACE-CPT
Biomechanist & Lab Manager, UCSF Human Performance Center

Mathias Sorensen, MS, ACE-CPT
Exercise Physiologist, UCSF Human Performance Center

RSVP TO ATTEND!

bit.ly/hpcimaging

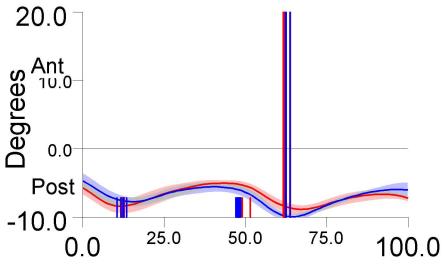
Table of Contents

RIGHT ---

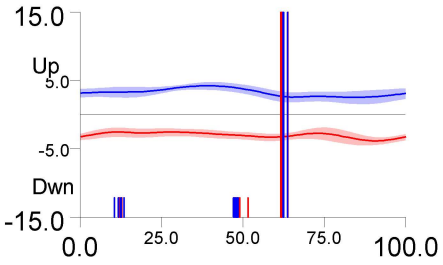
Fixed Walk Kinematics Mean

LEFT ---

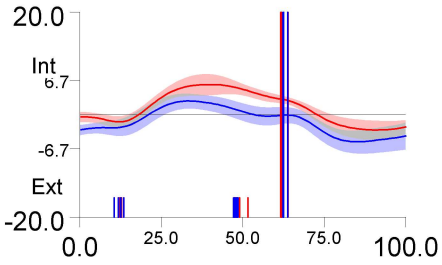
Trunk Tilt



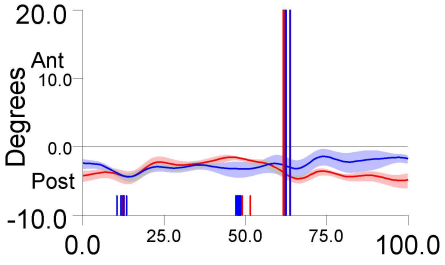
Trunk Lateral Bend



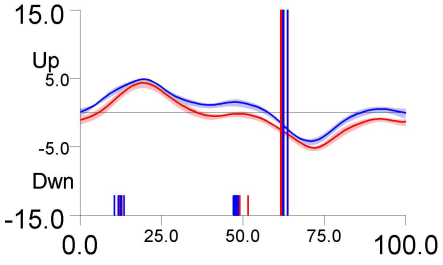
Trunk Rotation



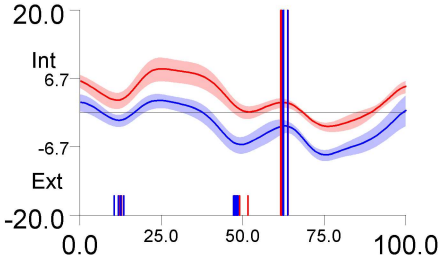
Pelvic Tilt



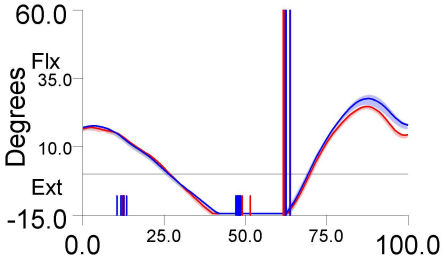
Pelvic Obliquity



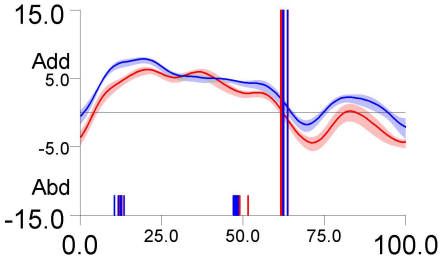
Pelvic Rotation



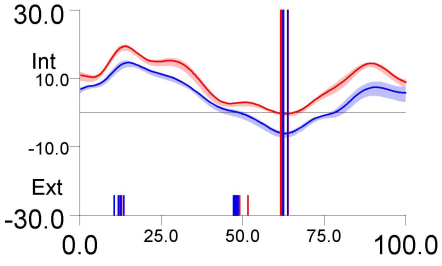
Hip Flexion



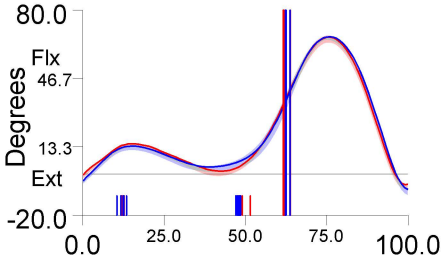
Hip Adduction



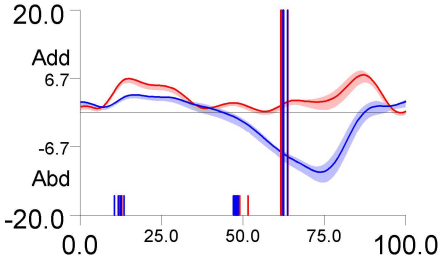
Hip Rotation



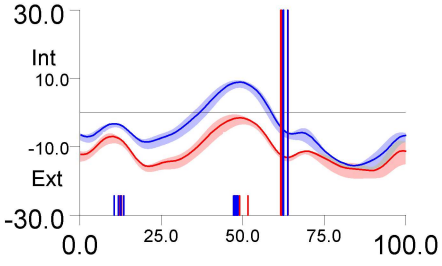
Knee Flexion



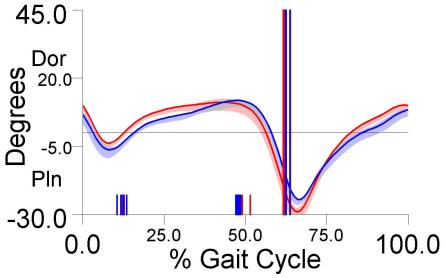
Knee Adduction



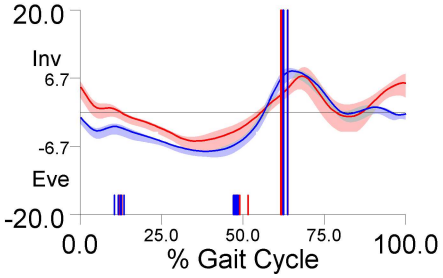
Knee Rotation



Ankle Dorsiflexion



Ankle Inversion



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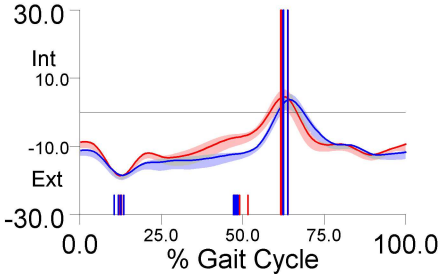
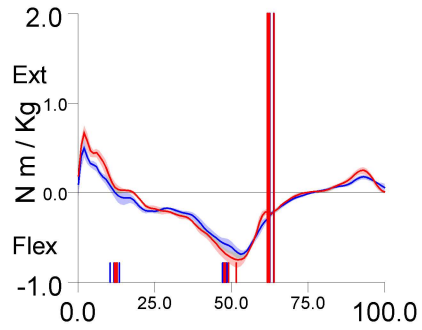
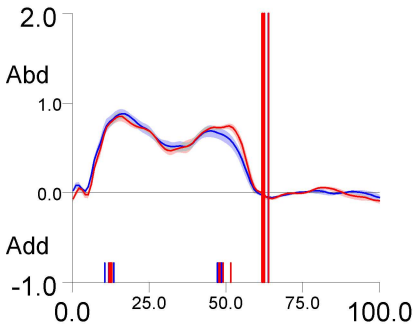


RIGHT Fixed Walk Kinetics Mean - Moments and GRF LEFT ---

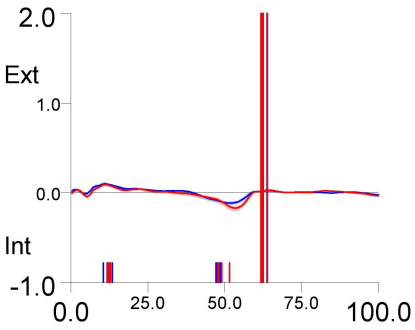
Hip Moment Sagittal



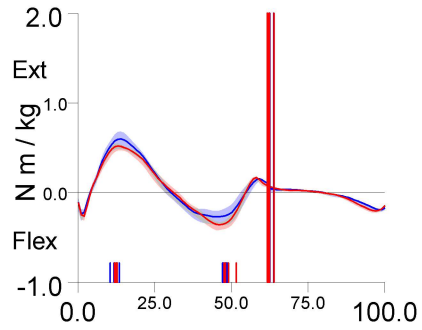
Hip Moment Coronal



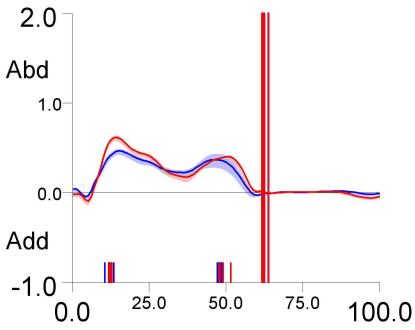
Hip Moment Transverse



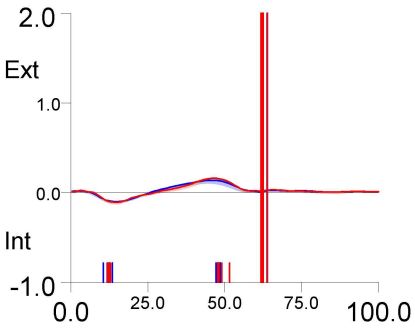
Knee Moment Sagittal



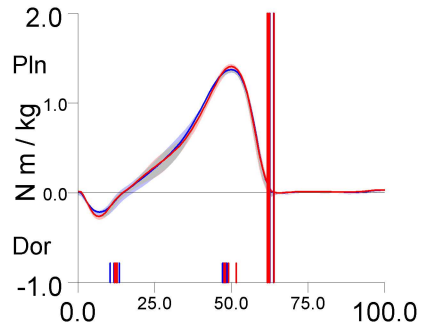
Knee Moment Coronal



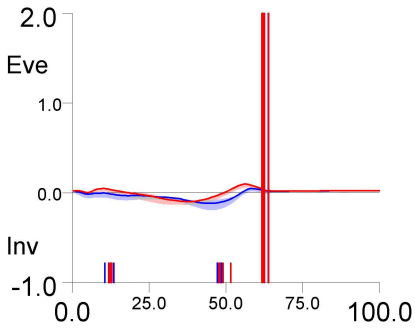
Knee Moment Transverse



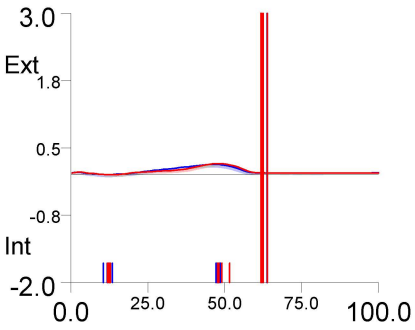
Ankle Moment Sagittal



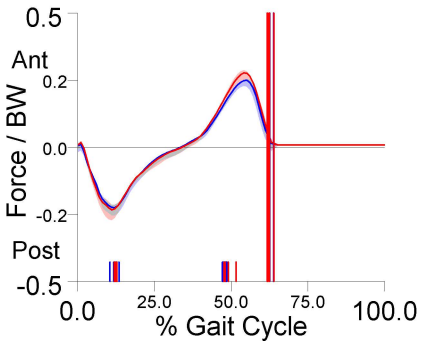
Ankle Moment Coronal



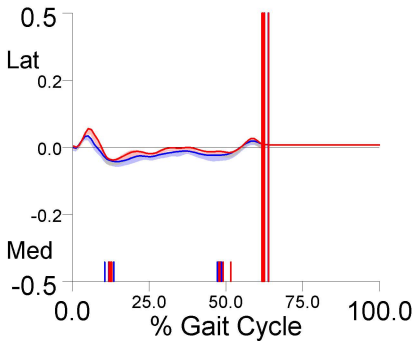
Ankle Moment Transverse



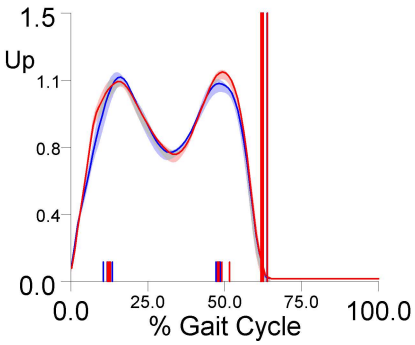
Ant-Post GRF



Lat-Med GRF



Vertical GRF

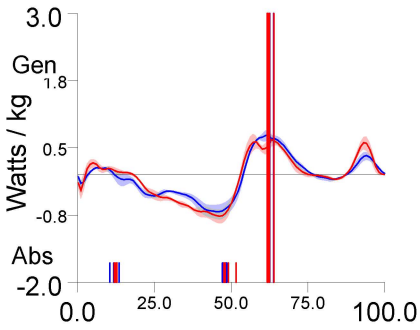


RIGHT ---

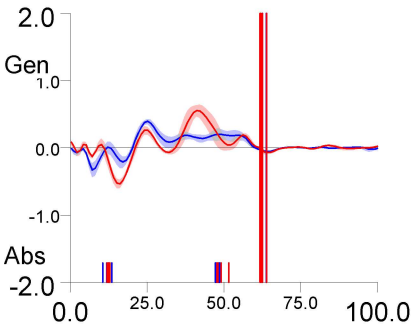
Fixed Walk Kinetics Mean - Power

LEFT ---

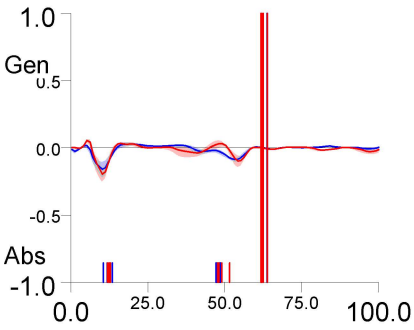
Hip Power Sagittal



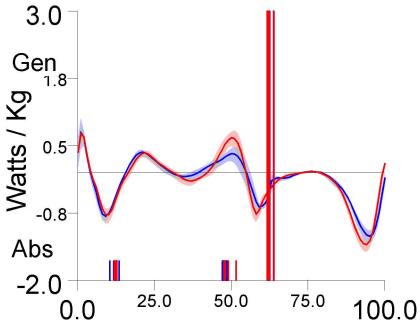
Hip Power Coronal



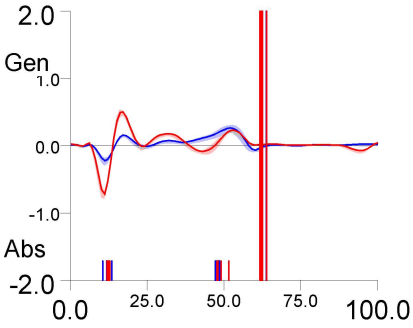
Hip Power Transverse



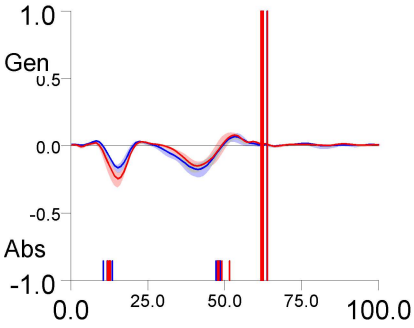
Knee Power Sagittal



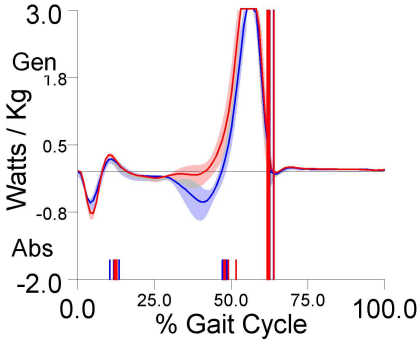
Knee Power Coronal



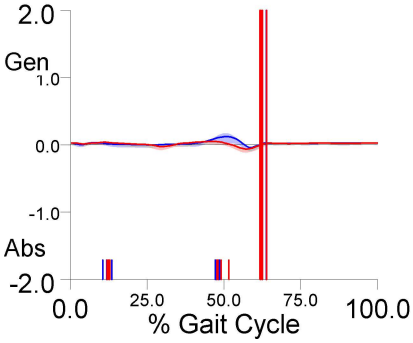
Knee Power Transverse



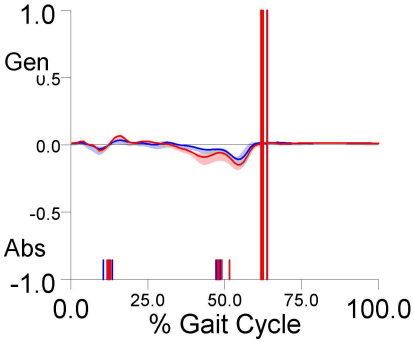
Ankle Power Sagittal



Ankle Power Coronal



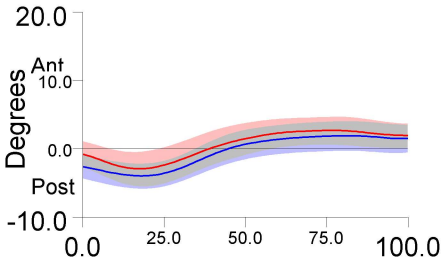
Ankle Power Transverse



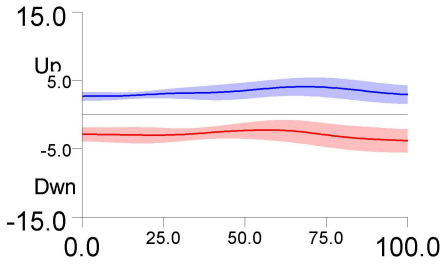
Stairs Up Kinematics Mean

RIGHT --- LEFT --- 6

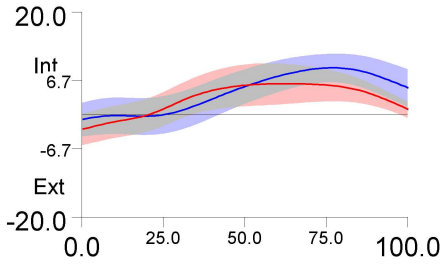
Trunk Tilt



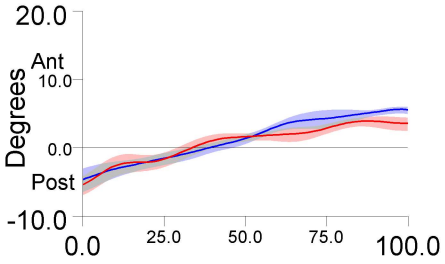
Trunk Lateral Bend



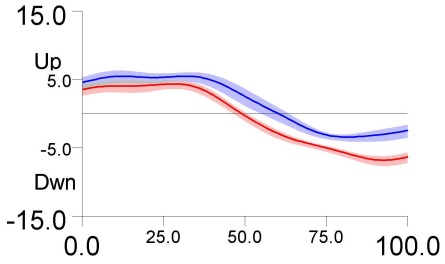
Trunk Rotation



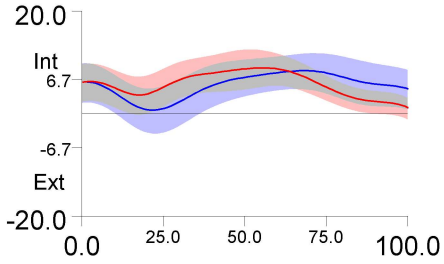
Pelvic Tilt



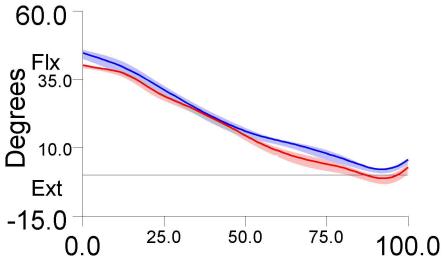
Pelvic Obliquity



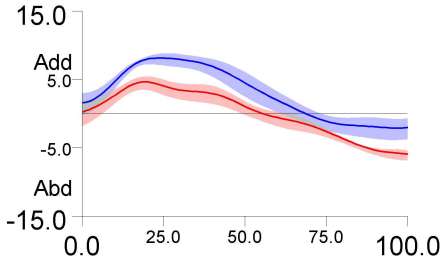
Pelvic Rotation



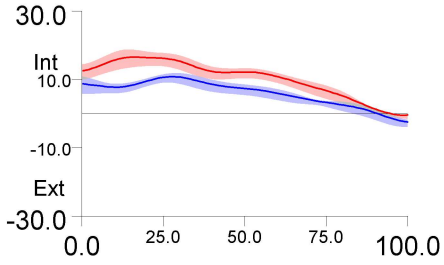
Hip Flexion



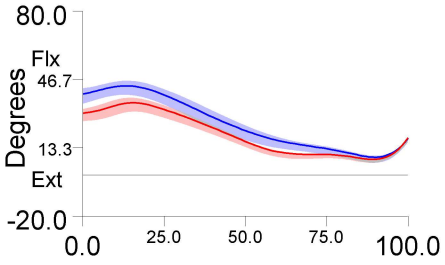
Hip Adduction



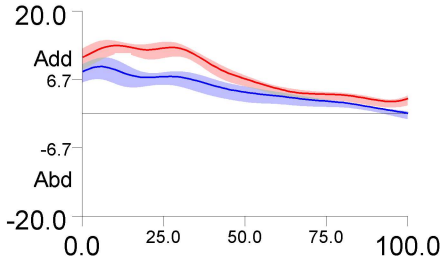
Hip Rotation



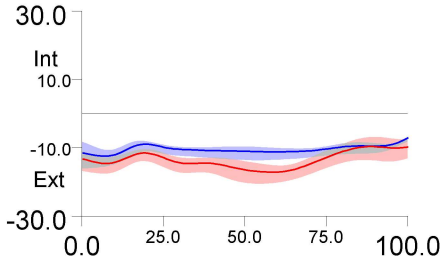
Knee Flexion



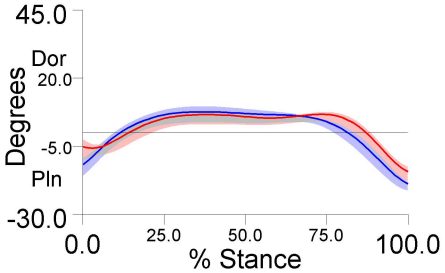
Knee Adduction



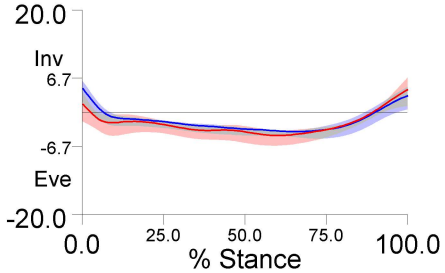
Knee Rotation



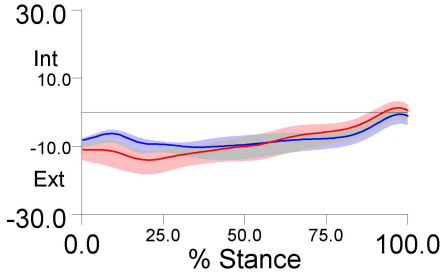
Ankle Dorsiflexion



Ankle Inversion

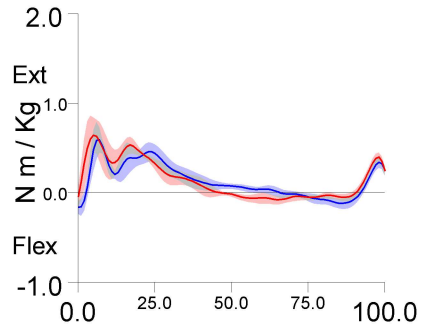


Ankle Rotation

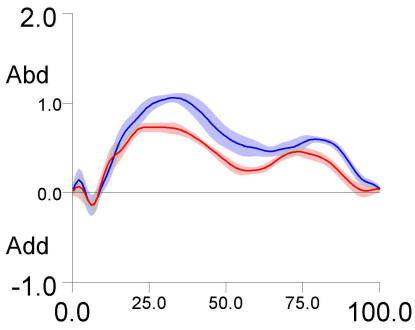


RIGHT --Stairs Up Kinetics Mean - Moments and GRF LEFT ---

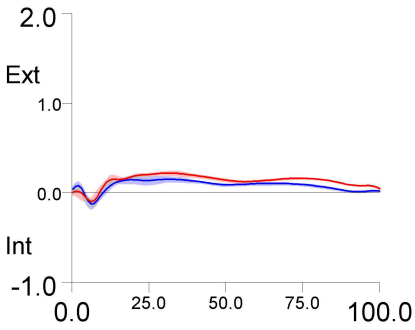
Hip Moment Sagittal



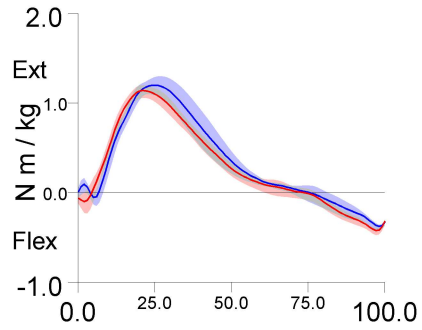
Hip Moment Coronal



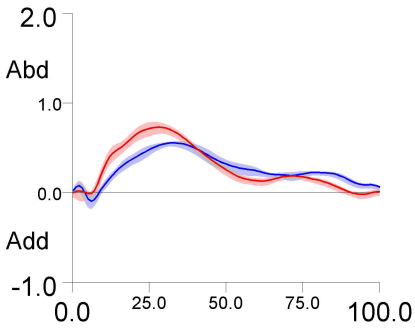
Hip Moment Transverse



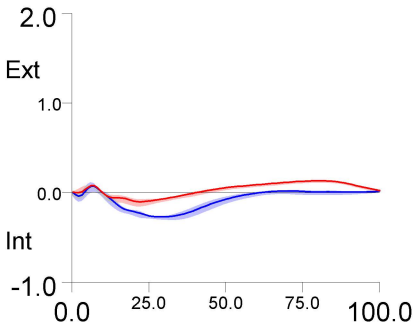
Knee Moment Sagittal



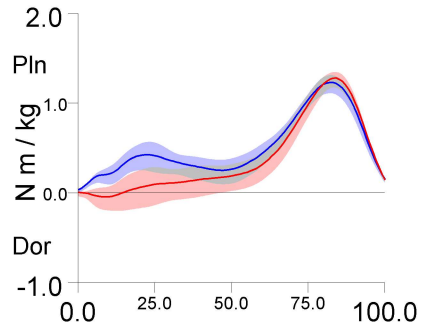
Knee Moment Coronal



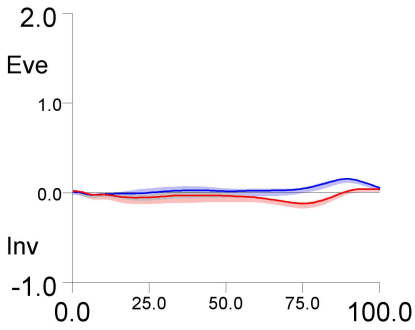
Knee Moment Transverse



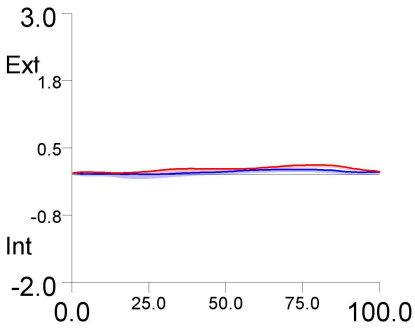
Ankle Moment Sagittal



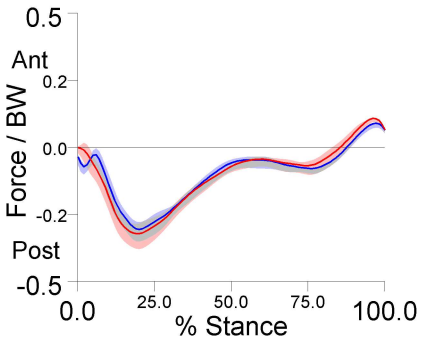
Ankle Moment Coronal



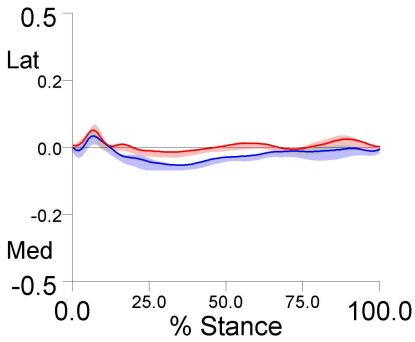
Ankle Moment Transverse



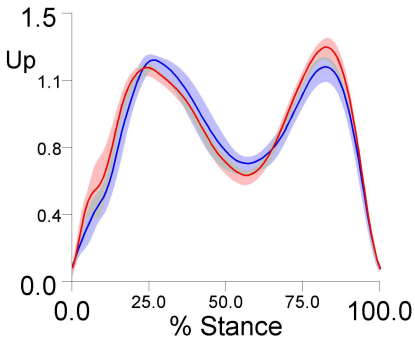
Ant-Post GRF



Lat-Med GRF



Vertical GRF

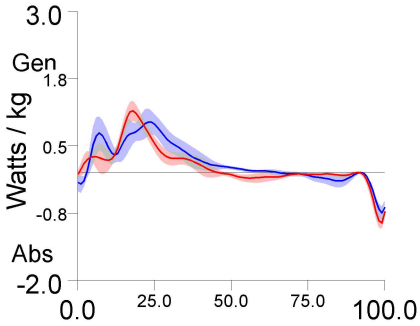


RIGHT ---

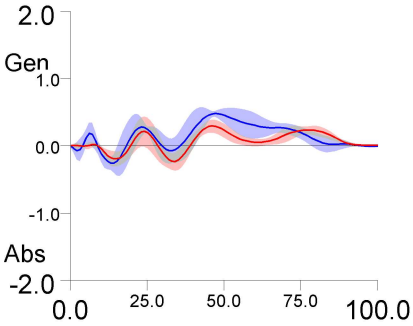
Stairs Up Kinetics Mean - Power

LEFT ---

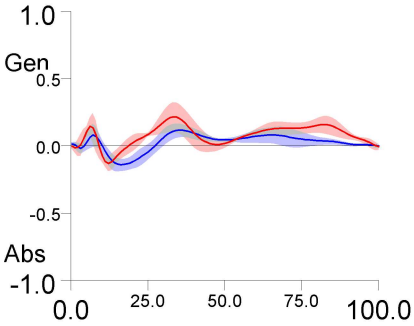
Hip Power Sagittal



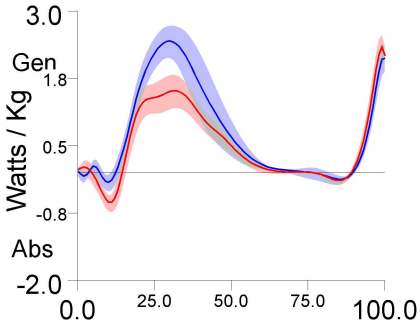
Hip Power Coronal



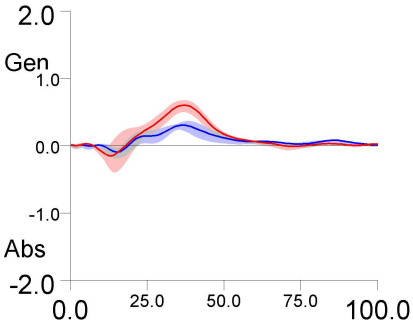
Hip Power Transverse



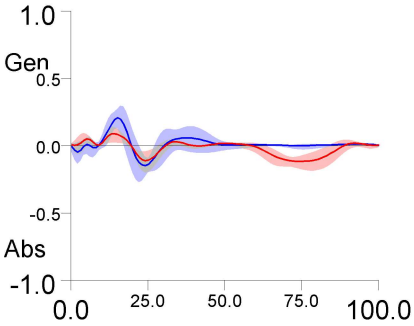
Knee Power Sagittal



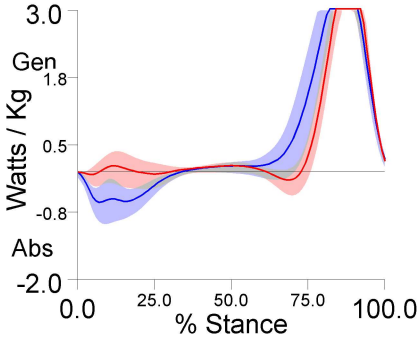
Knee Power Coronal



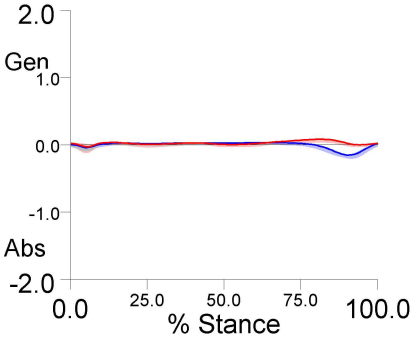
Knee Power Transverse



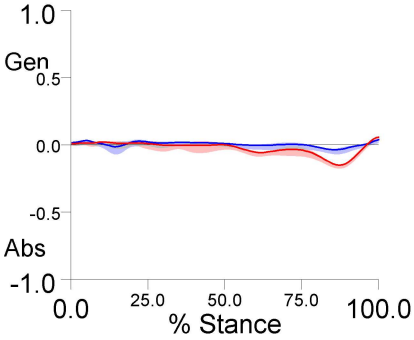
Ankle Power Sagittal



Ankle Power Coronal



Ankle Power Transverse

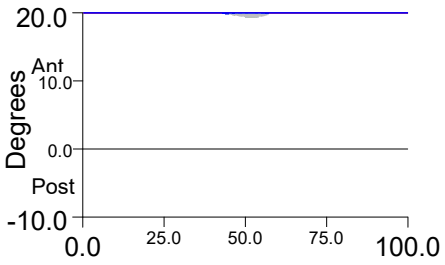


RIGHT ---

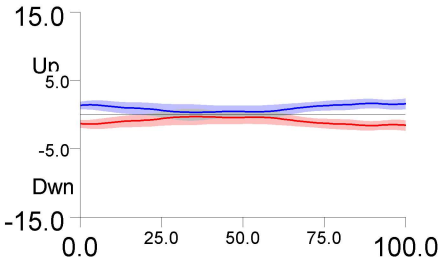
Sit to Stand Fast Kinematics Mean

LEFT ---

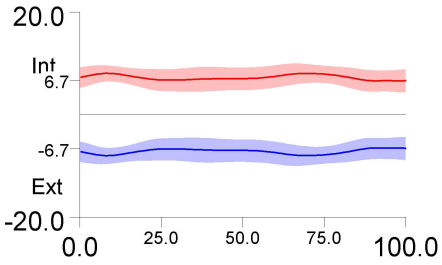
Trunk Tilt



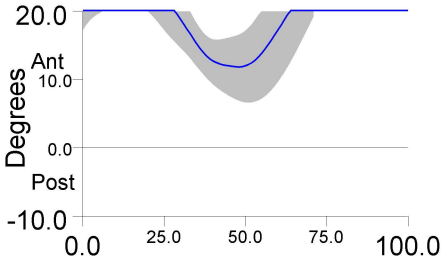
Trunk Lateral Bend



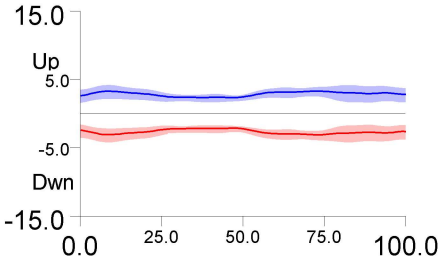
Trunk Rotation



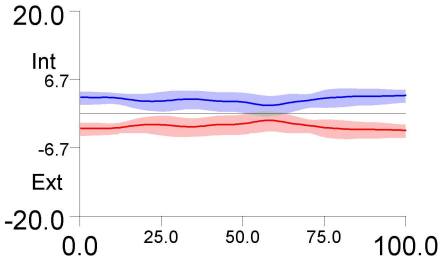
Pelvic Tilt



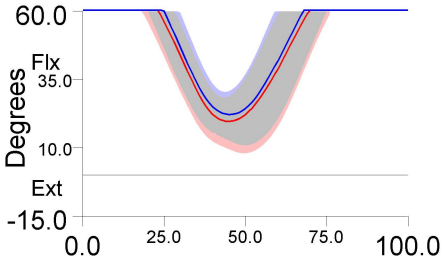
Pelvic Obliquity



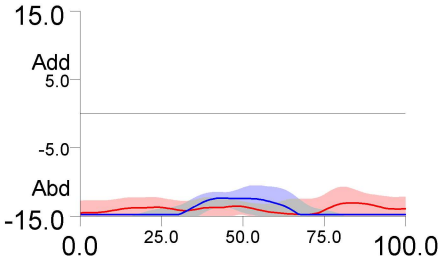
Pelvic Rotation



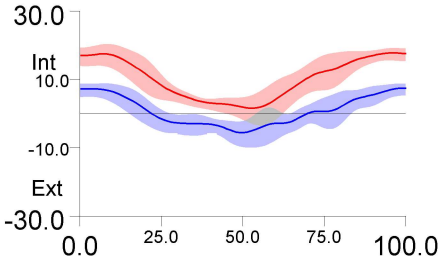
Hip Flexion



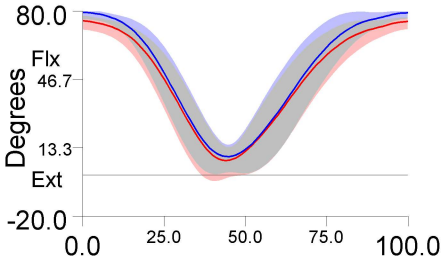
Hip Adduction



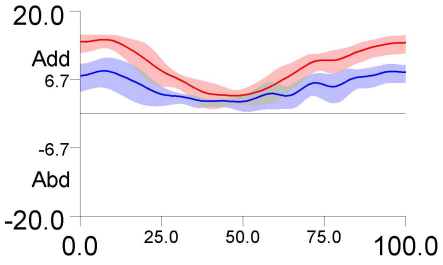
Hip Rotation



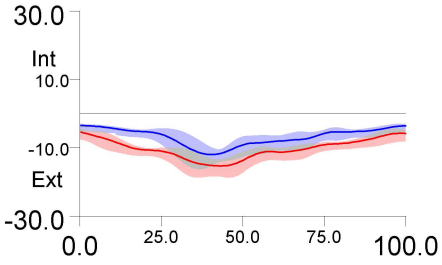
Knee Flexion



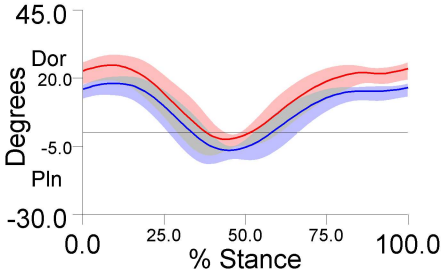
Knee Adduction



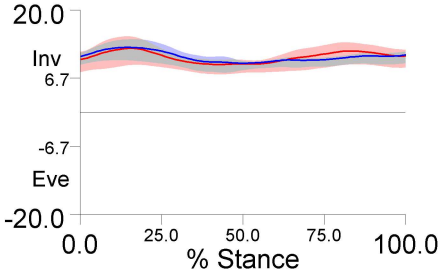
Knee Rotation



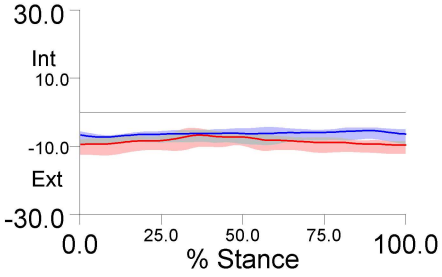
Ankle Dorsiflexion



Ankle Inversion

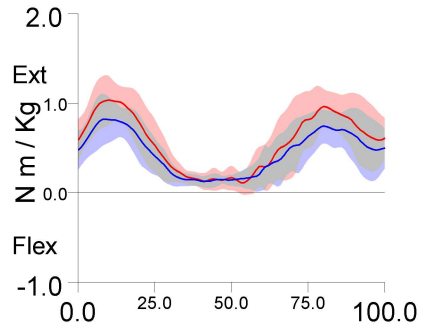


Ankle Rotation

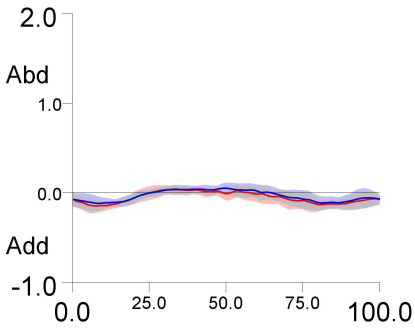


Sit to Stand Fast Kinetics Mean - Moments and GRF FT --- 10

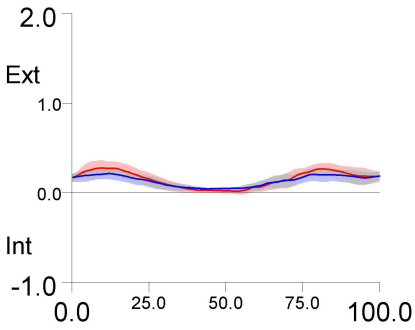
Hip Moment Sagittal



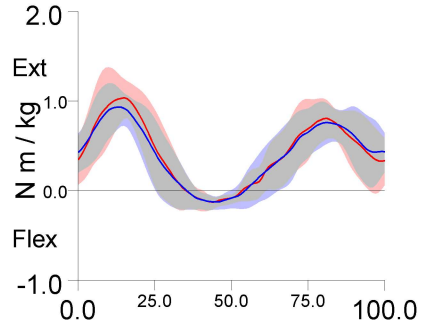
Hip Moment Coronal



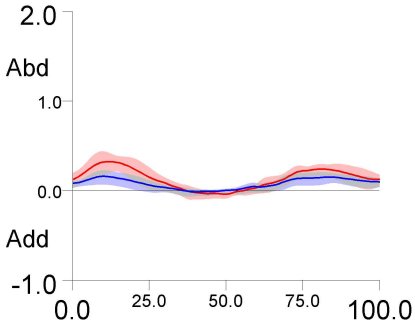
Hip Moment Transverse



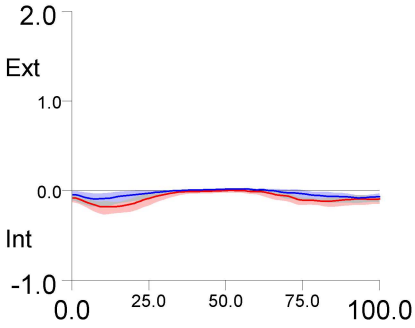
Knee Moment Sagittal



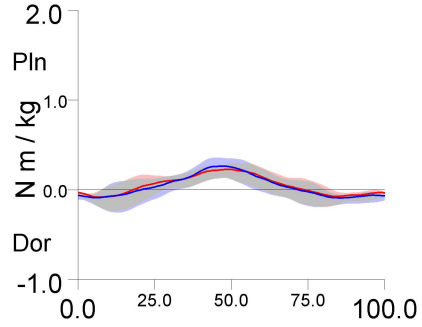
Knee Moment Coronal



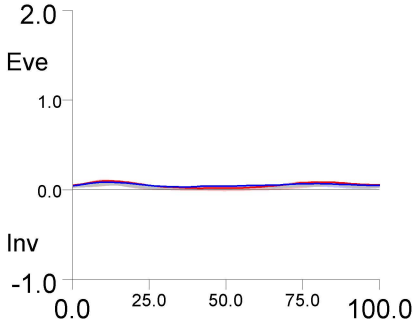
Knee Moment Transverse



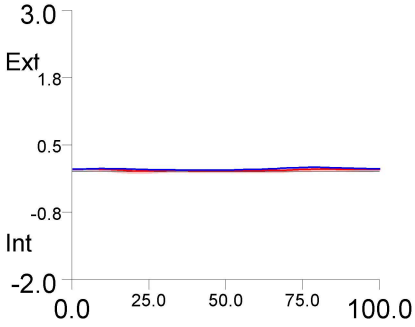
Ankle Moment Sagittal



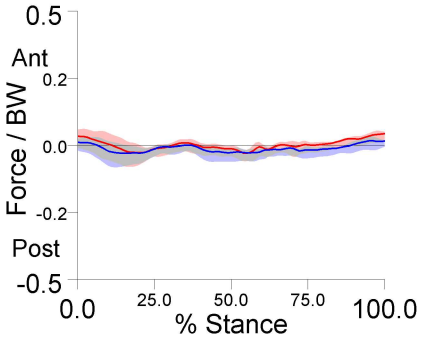
Ankle Moment Coronal



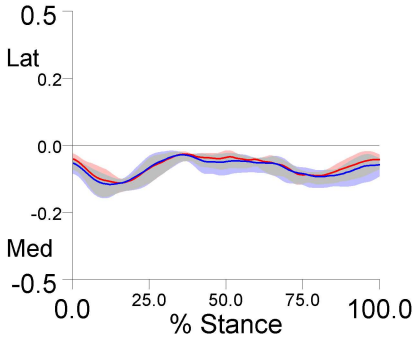
Ankle Moment Transverse



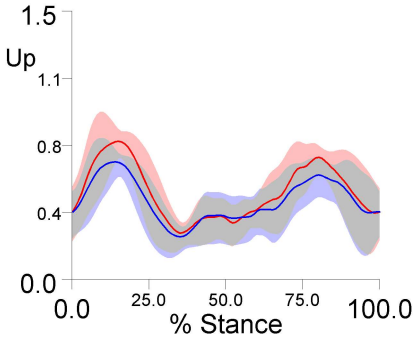
Ant-Post GRF



Lat-Med GRF

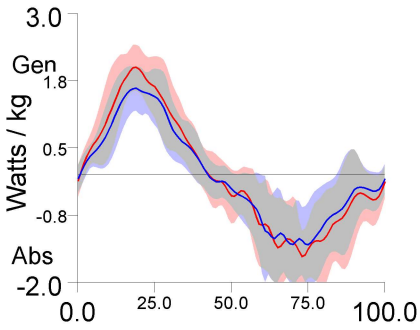


Vertical GRF

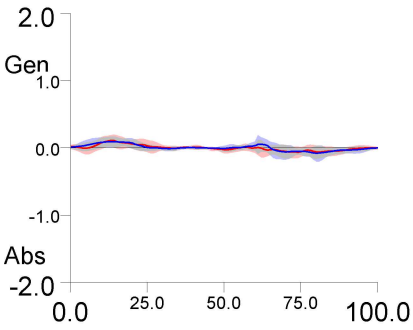


RIGHT ---Sit to Stand Fast Kinetics Mean - Power LEFT --- 11

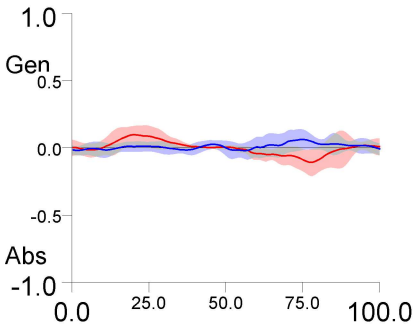
Hip Power Sagittal



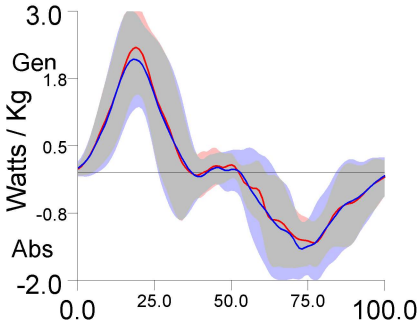
Hip Power Coronal



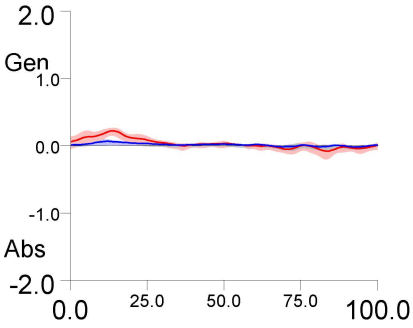
Hip Power Transverse



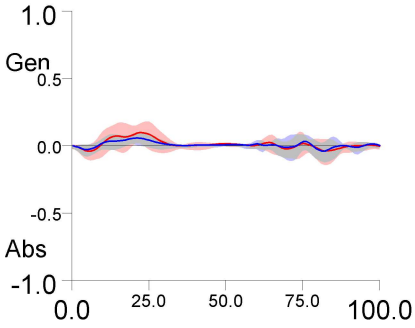
Knee Power Sagittal



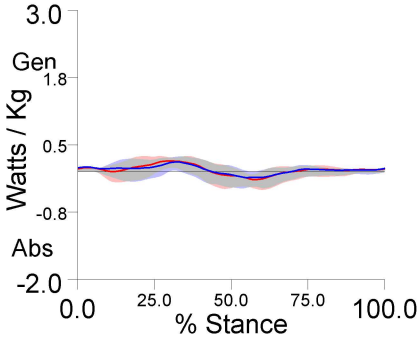
Knee Power Coronal



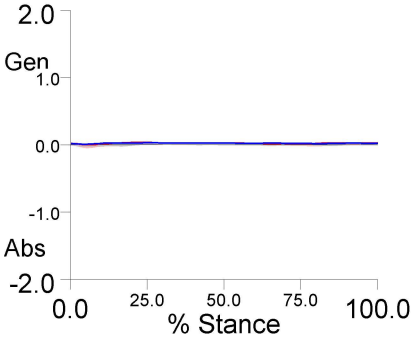
Knee Power Transverse



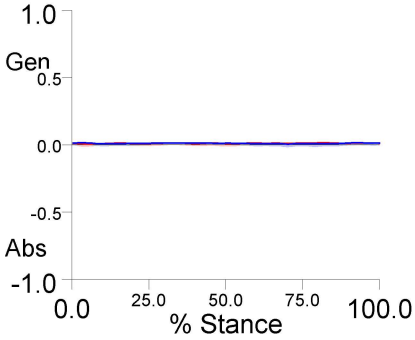
Ankle Power Sagittal



Ankle Power Coronal



Ankle Power Transverse



UCSF Orthopaedic Institute
Human Performance Center

Patient Information

Name	Age	Height	Weight	Sex			
Test Protocol							
Test degree	Maximal	Exercise Device	Bike				
Test Environment							
Insp. temp.	23 deg C	Baro. pressure	764 mmHg	Insp. humidity	17%		
Exp. flow temp.	Mean of room temp. and 37.0 deg C						
Insp. O2	20.94000053%		Insp. CO2	0.029999999%			
Selected Flowmeter	0-800 Lpm						
STPD to BTPS	1.203631282	O2 Gain	0.000122636	CO2-NL gain	9.07884E-05		
Base Values for Sampling							
Base O2	20.94000053%	Base CO2	0.029999999%	Measured O2	20.89337158%	Measured CO2	0.059719291%

TIME	VO2	VCO2	VO2/kg	RER	HR	RR	VE/VO2	VE/VCO2	VE	CHOmin	FATmin	%CHO	%FAT	KCHO	KFAT	WorkR	Vt	PIoO2	PhiCO2	METS	WorkR	RPM	FATmin
min	*L/min*	*L/min*	*ml/kg/m*		*bpm*	*BPM*	*ST/ST*	*ST/ST*	*L/min*	*g/min*	*g/min*	*%*	*%*	*Kcal/m*	*Kcal/m*	*W*	*L*	*mmHg*	*mmHg*		*W*		*g/min*
0:32	0.85	0.65	8.84	0.77	99	20.51	23.05	30.06	19.64	0.21	0.34	21.70	78.57	0.88	3.18	0.00	0.96	127.21	26.03	2.53	0.00	58.86	0.34
1:00	0.99	0.79	10.28	0.80	100	21.37	22.77	28.50	22.55	0.37	0.34	33.10	67.25	1.57	3.18	0.00	1.06	126.79	27.33	2.94	0.00	89.85	0.34
1:31	1.05	0.85	10.89	0.81	99	17.60	20.31	25.18	21.31	0.43	0.34	35.77	64.61	1.80	3.25	19.55	1.21	122.64	31.02	3.11	19.55	92.59	0.34
2:01	1.41	1.07	14.65	0.76	100	17.72	18.61	24.58	26.27	0.29	0.58	18.22	82.03	1.22	5.48	20.33	1.48	119.58	31.62	4.18	20.33	97.90	0.58
2:30	1.31	0.92	13.64	0.70	100	20.78	18.99	27.21	24.96	-0.05	0.67	-3.35	103.44	-0.21	6.35	40.00	1.20	121.09	29.03	3.90	40.00	98.23	0.67
3:01	1.34	0.92	13.90	0.69	104	19.11	18.24	26.43	24.42	-0.09	0.70	-6.27	106.34	-0.39	6.63	40.49	1.28	119.61	29.43	3.97	40.49	101.15	0.70
3:32	1.59	1.15	16.48	0.72	104	17.69	19.16	26.45	30.42	0.11	0.74	6.39	93.78	0.48	6.99	60.00	1.72	121.05	29.60	4.71	60.00	93.88	0.74
4:01	1.28	0.96	13.31	0.75	109	16.48	19.40	25.87	24.87	0.23	0.54	15.63	84.60	0.95	5.13	60.33	1.51	121.17	30.15	3.80	60.33	95.83	0.54
4:32	1.79	1.27	18.54	0.71	110.5	19.10	18.04	25.33	32.23	0.04	0.87	2.04	98.09	0.17	8.21	80.00	1.69	118.59	30.77	5.30	80.00	94.47	0.87
5:01	1.59	1.21	16.48	0.76	111.5	16.55	18.01	23.67	28.60	0.35	0.64	19.55	80.70	1.47	6.07	80.51	1.73	118.35	33.00	4.71	80.51	94.72	0.64
5:32	1.64	1.28	17.02	0.78	112	15.68	17.48	22.32	28.66	0.51	0.60	27.55	72.77	2.15	5.68	100.00	1.83	117.02	34.85	4.86	100.00	95.06	0.60
6:00	1.95	1.42	20.27	0.73	118	17.34	16.61	22.85	32.43	0.16	0.90	7.34	92.83	0.67	8.52	100.00	1.87	115.25	34.32	5.79	100.00	97.15	0.90
6:30	2.07	1.48	21.45	0.72	118.5	15.85	16.60	23.16	34.32	0.09	0.99	3.67	96.48	0.36	9.35	119.39	2.17	115.25	33.59	6.13	119.39	97.40	0.99
7:00	2.22	1.63	23.01	0.73	121	15.83	16.04	21.87	35.58	0.24	1.00	9.81	90.38	1.02	9.44	120.00	2.25	113.61	35.66	6.58	120.00	96.10	1.00
7:31	2.30	1.76	23.83	0.76	123	19.46	17.83	23.30	40.94	0.55	0.91	21.08	79.19	2.30	8.62	139.89	2.10	117.86	33.36	6.81	139.89	94.24	0.91
8:00	2.24	1.74	23.19	0.78	124	22.60	18.70	23.96	41.80	0.68	0.83	26.64	73.67	2.83	7.84	140.00	1.85	119.70	32.44	6.63	140.00	91.61	0.83
8:30	2.33	1.80	24.21	0.77	127	20.11	17.07	22.12	39.82	0.62	0.90	23.41	76.87	2.59	8.52	159.90	1.98	116.05	35.25	6.92	159.90	91.05	0.90
9:00	2.67	2.23	27.73	0.83	133	22.11	17.94	21.53	47.95	1.39	0.75	45.07	55.37	5.80	7.13	160.00	2.17	117.72	35.94	7.92	160.00	91.68	0.75
9:33	2.39	1.94	24.78	0.81	134	20.24	17.67	21.74	42.20	1.04	0.75	38.05	62.34	4.36	7.14	179.64	2.09	117.16	36.17	7.08	179.64	90.06	0.75
10:00	2.92	2.25	30.32	0.77	135.5	21.76	17.32	22.53	50.60	0.74	1.14	22.37	77.91	3.10	10.80	180.00	2.33	116.71	34.41	8.66	180.00	91.65	1.14

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Performance Evaluation

Results

Name:	Date:

Age:	**Test Type:**	VO2 Max
Sex:	**Fasted:**	n/a
Height:	**Mode:**	Bike
Weight:	**Protocol:**	Ramp Test (20wpm)

Thank you for using UCSF Human Performance Center. Performance testing is a tool to help you optimize your training and enhance performance. By analyzing the exchange of respiratory gases (O2 and CO2) breath-by-breath, measuring blood lactate levels, and identifying other key variables, we can estimate your current fitness level as well as recommend areas where you may be able to improve performance in your sport. This report provides you with a general overview of your evaluation results, maximal values, comparative norms, and suggested training zones. Each evaluation performed will include a table and/or graph containing a brief overview of your results along with notes regarding your performance goals. Included in the packet contains your suggested training zones as well as samples of exercise routines that may improve areas of weakness.

If you have any questions about your current report, or interest in future testing, please do not hesitate to give us a call at (415) 514-6077 or reach out to our Exercise Physiologist, Mathias Sorensen, at mathias.sorensen@ucsf.edu

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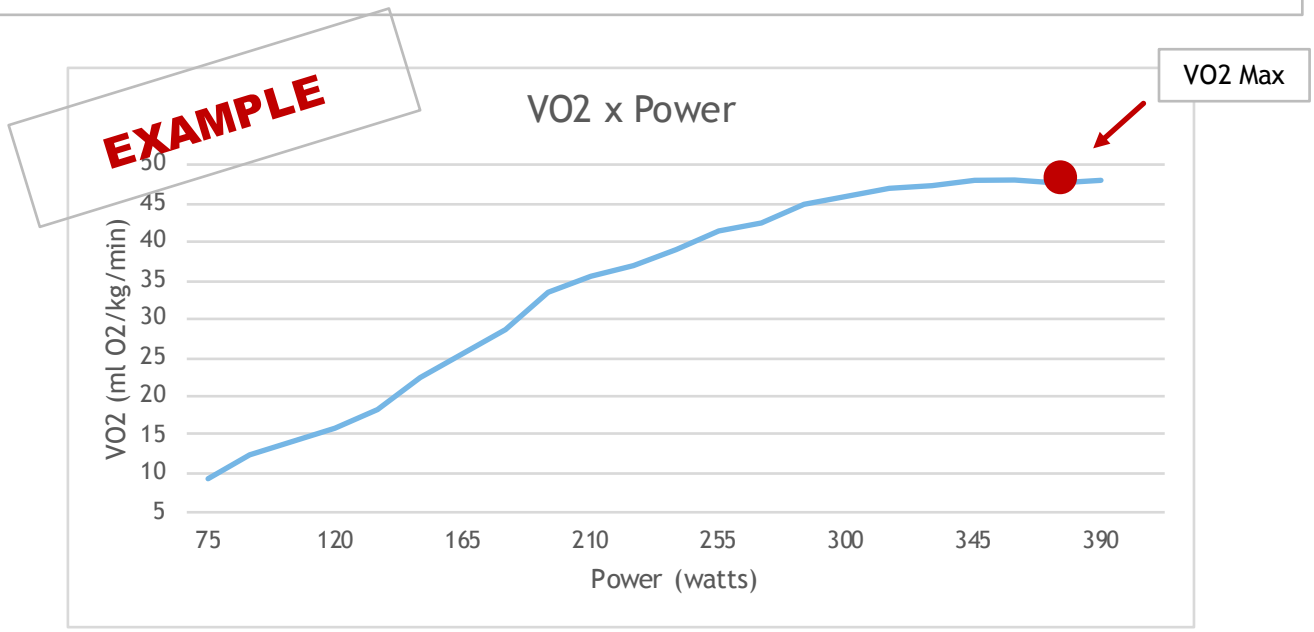
Results: Overview

Maximum Ventilatory Values				
VO2 Max (Absolute):	4.28 L/min	VO2 Max (Relative):	44.42	ml/kg/min
Minute Ventilation (VE):	103 L/min	Respiratory Rate:	37	br/min
VO2 Max Classification (norm):		VO2 Max Ranking:		percentile

What is VO2max and what does it tell me?

VO2max refers to the maximum capacity the body has to uptake oxygen; it is regarded as the best measurement of maximal aerobic capacity. Consider it the *size* of our engine. As exercise intensity increases, our body's consumption of oxygen increases linearly until a plateau is reached (the VO2max). This is measured as both absolute (Liters O2 per minute) and relative (mililiters O2 per *kilogram body weight* per min). Relative VO2 max is a direct indication of how efficient *your* body is at both uptake and utilization of oxygen for exercise.



Since our ability to exercise (aerobically) is limited by our ability to transport oxygen to the muscles, a high VO2max is one particular indicator of athletic potential. Most elite athletes will have VO2max values over 60ml/kg/min! However, this number alone is not a guarantee of elite performance, as there are other factors such as Blood Lactate concentration that affect peak performance. As such, high VO2max may indicate an athlete's potential for superior aerobic endurance, but does not necessarily determine the winner of a race.

Note: A lower VO2 max is one of the greatest predictors of early all-cause mortality related to cardiovascular, metabolic, or renal disease. Increasing VO2 max will almost always improve overall health outside of fitness and sports performance.

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Results: VO2 Normative Values

Men: Age Groups & VO2 Max						
Percentile	**Classification**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**
95th +	Superior	66 +	59 +	56 +	51 +	43 +
80th - 95th	Excellent	57 - 65	51 - 58	46 - 55	41 - 50	36 - 42
60th - 80th	Good	50 - 56	45 - 50	40 - 45	35 - 40	30 - 35
40th - 60th	Fair	45 - 49	40 - 43	35 - 39	31 - 34	26 - 29
20th - 40th	Poor	38 - 44	34 - 39	30 - 34	26 - 30	22 - 25
10th - 20th	Very Poor	32 - 37	29 - 32	26 - 29	22 - 24	18 - 21
< 10th	Deconditioned	< 29	< 29	< 24	< 21	< 17

Women: Age Groups & VO2 Max						
Percentile	**Classification**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**
95th +	Superior	56 +	46 +	42 +	36 +	29 +
80th - 95th	Excellent	46 - 52	37 - 42	34 - 39	29 - 32	25 - 27
60th - 80th	Good	41 - 45	32 - 36	29 - 33	25 - 28	22 - 24
40th - 60th	Fair	34 - 40	28 - 31	25 - 28	22 - 24	19 - 21
20th - 40th	Poor	28 - 33	24 - 27	21 - 24	19 - 21	17 - 18
10th - 20th	Very Poor	24 - 26	21 - 23	18 - 20	17 - 18	15 - 16
< 10th	Deconditioned	< 22	< 19	< 17	< 16	< 14

How did I compare to others?

Your VO2 max results are classified in the **Fair** category and an estimated **50th** percentile. Your VO2 max is compared with normative values provided by The American College of Sports Medicine (ACSM) based on thousands of other participants in the same age and sex as yourself.

While comparing yourself to normative data may be helpful to estimate your fitness ranking, it is important to remember that genetic influences govern a portion of your VO2 max capacity. Similarly, it is also best to compete against yourself and identify stategies that are personalized to your improvements regardless of where you rank.

"Comparison is the thief of joy" - Theodore Roosevelt

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Results: FTP & Power Response

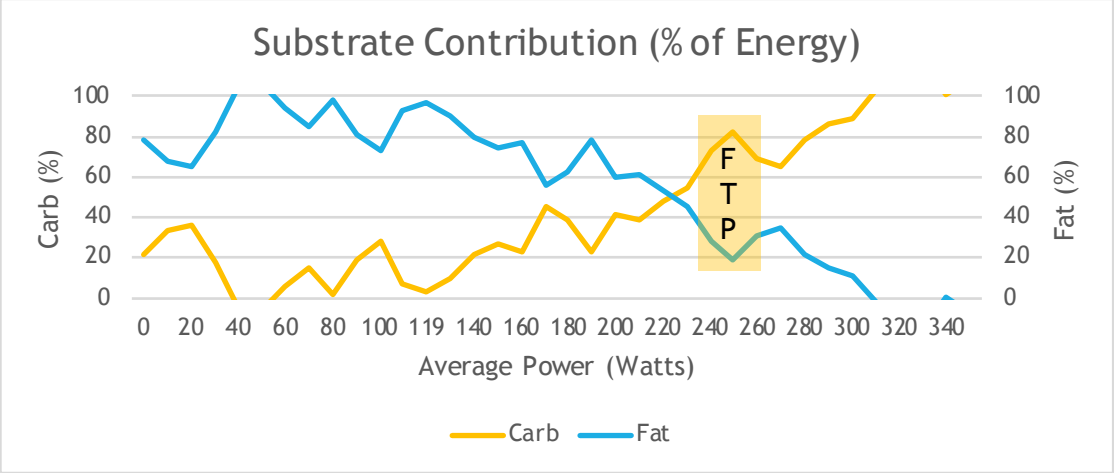
Heart Rate and Ventilatory Response to Exercise						
HR rest:	bpm		HR max:	178	bpm	
Power & HR at VT1 :	180	watts	137	bpm	77%	% max HR
Power & HR at VT2 :	260	watts	158	bpm	89%	% max HR
Power Response						
Est. Functional Threshold Power (FTP):			249	Watts	2.59	Watts/kg
Est. HR at FTP:	154	bpm	87%	max HR	75%	VO2 max

FTP Norms (Watt/kg)									
World Class		Excellent (Cat 1)		Good (Cat 3)		Moderate (Cat 4)		Novice (Cat 5)	
Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
6.4 - 5.15	5.69 - 4.54	5.15 - 4.18	4.54 - 3.64	4.18 - 3.64	3.64 - 3.14	3.63 - 2.93	3.14 - 2.49	2.93 - 2.4	2.49 - 1.99

FTP (Functional Threshold Power) is a critical metric in cycling that measures a rider's maximum sustainable power output for one hour. This measurement is used to set training zones and track progress over time, allowing cyclists to monitory and improve their overall performance. FTP is measured both in absolute values (watts) as well as relative values (watts/kg) which compares a cyclist's power output to their weight. The higher a cyclist's watts/kg ratio, the faster they will be able to ride.

FTP is best measured in a time-trial scenario, often requiring a cyclist to ride as hard as possible for 60 minutes. However, less-intensive tests can be used to estimate FTP, such as riding a 20-minute time trial as fast as possible and multiplying the average power during this 20-minute period by 95% (0.95). A third option is to perform a ramp test and multiplying the highest 60-second power output by 75% (0.75). Your estimated FTP is calculated from the VO2-max ramp test protocol. This is only an estimate, however, as a proper ramp test protocol uses specific pre-determined power outputs per stage.

The chart below shows your substrate utilization contribution. FTP can be estimated by identifying the point where **most** of your energy is derived from carbohydrates compared to fats (usually around 80:20 ratio) as this is indicative of a **sustainable** yet **fatigue-inducing** output.



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Results: HR Response (cont.)

The above chart shows your HR plotted against your VO2 during the test. As you can see, HR and VO2 have a near-linear relationship. This is useful to know for training intensities, knowing that, for example, 65% of your HR max equates to 55% VO2 max (example only - not a true conversion). As such, it's easier to train based off of HR zones than VO2 zones, since most people have access to a heart rate monitor. See the TRAINING page for a detailed breakdown of your heart rate based training zones.

Factors that can affect HR Response:

- Stimulants/Caffiene - increases resting HR & possibly submaximal HR
- Heat & Humidity - increases submaximal & maximal HR
- Fatigue/Overtraining - decreases resting HR; blunts submaximal & maximal HR
- Medication - significant reduction/blunt in active & submaximal HR
- Illness/Infection - significant increase in resting HR

One of the most common indications of overtraining is a significant reduction your ability to hit HRmax or within 95% of HRmax. This can limit your ability to perform at maximal output and indicates that a period of rest or very low intensity (recovery days) is recommended.

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Results: Ventilatory Response

VE/VO2 ratio represents the relationship between ventilation (VE) and oxygen consumption (VO2). This ratio can serve as an indirect marker of the *efficiency* of breathing during exercise. At lower exercise intensities, the VE/VO2 ratio tends to remain relatively low, indicating efficient oxygen uptake by the body. However, as exercise intensity increases beyond VT1, the VE/VO2 ratio typically rises due to the increased demand for oxygen and subsequent increase in ventilation.

Ventilatory Threshold 1 (VT1) is a physiological marker during exercise that indicates the point where there's a significant increase in ventilation (breathing rate) in response to the body's increased demand for oxygen. VT1 is characterized by a noticeable rise in carbon dioxide output, an increase in blood lactate levels, and a deviation from the linear relationship between ventilation (VE) and oxygen consumption (VO2) established from a "baseline".

VE/VCO2, ratio reflects how much ventilation is required to eliminate a given amount of carbon dioxide produced by the body. During exercise, as metabolic demands increase, there's a proportional increase in VCO2 due to increased metabolism. The VE/VCO2 ratio helps to quantify the efficiency of the respiratory system in removing this additional carbon dioxide.

Ventilatory Threshold 2 (VT2) represents an increased respiration of CO2 resulting from metabolization of carbohydrates (byproducts of carbohydrates result in carbon molecules) and a substantial increase in ventilation to rapidly expel carbon dioxide. This is a critical marker in exercise where the body transitions to higher-intensity outputs. Training at this threshold may improve performance and the body's ability to maintain higher levels of blood-lactate concentration before critical acid-base imbalances occur.

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Results: Training Zones

Based on Ventilatory Threshold & FTP			
Zone	**HR (minimum)**	**HR (maximum)**	**Purpose/Outcome**
1	< 131 bpm Watts to Watts		Active Recovery
2	137 bpm to 147 bpm Watts to Watts		Aerobic Threshold; Steady-state
3	148 bpm to 157 bpm Watts to Watts		Tempo
4	158 bpm to 168 bpm Watts to Watts		Lactate Threshold; Interval
5a	169 bpm to 175 bpm Watts to Watts		Aerobic Capacity
5b	176 bpm to 178 bpm + Watts to Watts		Anaerobic Capacity; Vlamax
5c	179 bpm to bpm + Watts to Watts		Neuromuscular Power

Training Zones Explained		
Zone	**Description**	**Duration**
1	This is useful for active recovery as it brings significant bloodflow to muscles without causing excessive metabolic stress.	6 hours +
2	This zone strengthens Type 1 fibers, increases mitochondrial and capilary density, and improves oxidation of fat as fuel.	2-3 hours
3	Falling between moderate and hard intensity, this zone will improve your Zone 2 speed by challenging aerobic endurance.	30-90 minutes
4	This zone improves your lactate tolerance and will enable longer durations of faster pacing before the crash and burn.	5-30 minutes
5a	Use this zone to push into vigorous intensity and improve maximum aerobic capacity (VO2 max).	1-5 minutes
5b	Similar to Zone 6, this high intensity zone will improve anaerobic metabolism and also help prolonged sustained near-max efforts.	30-60 seconds
5c	This supramaximal Zone is designed to develop explosive power by facilitating Type 2 fibers and new neural networks.	1-30 seconds

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Training: Applied Training Priciples

Two of the primary training principles that govern improvement in fitness are the **S.A.I.D.** Principle and the Overload Principle.

Specific Adaptations to Imposed Demands (SAID)

The SAID Principle states that our physiology will only adapt in response to the stimuli that we encounter. Therefore, the improved physical fitness will (generally) only be a result of the physiological pathways that are challenged during training, meaning that performing long durations of light intensity will **not** improve your ability to perform short durations of vigorous intensity. Adaptations are secific to the demands placed on the body during training. This is why sprinters are *really* good at running short distances *very* quickly, but would otherwise be no better than the average person at running a marathon.

However, there is a degree of translational adaptation that can be observed with cardiovascular training. For example, training in Zone 2 will build a stronger base and can also improve VO2 max as a secondary outcome. Identifying your top training priority, and then applying these pricinciples to focus on that specific type of training will lead you to results faster and more efficiently.

Overload Principle

The Overload Principle refers to the theory that training intensities must surpass a threshold that elicits a response to improve the (afforementioned) demands. For example, to improve your 1-mile pace, you must systematically train at speeds *faster* than your current 1-mile pace. Similarly, if you want to improve your lactate threshold, you need to be training at *or slightly beyond* that threshold. Failing to properly induce Overload will result in plateaus, and eventually, a decrease in physical fitness ("use it or lose it").

Lastly, one of the most underrated components of improving physical fitness is rest. Believe it or not, resting is where fitness improvements are made. This is the time where the body can fully repair and replenish various nutrients, hormones, proteins, and other mechanisms that are placed under stress during training. Failing to get adequate rest, both intraworkout and just overall recovery will likely blunt your capacity to imrpove your fitness.

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Training: Improving Fitness

Building a strong base for long-duration conditioning: Zone 2

This zone should be the bulk of your training as they build an effective cardiovascular foundation. Training in Zone 2 enables you to average a higher power output at a lower metabolic cost as a result of improved strength and proliferation in slow twitch, oxidative (type 1) muscle fibers that contain high concentrations of mitochondria and blood capilaries. These cells allow for greater gas exchange (O2 and CO2) within the muscle during cellular respiration as well as better utilization of fats as a source of energy. Unless you are specifically training for an upcomming race or competition, this should be approximately 80% of your training volume. Note: the following training template is an example of progression and may not provide enough training stimulus to highly developed cyclists.

Week	Day	Workout	Week	Day	Workout
1	1	45 mins Zone 2	4	1	90 mins Zone 2
	2	rest		2	rest
	3	60 mins Zone 2		3	105 mins Zone 2
	4	rest		4	rest
	5	60 mins Zone 2		5	105 mins Zone 2
	6	30-45 min Zone 2*		6	45-60 min Zone 2**
	7	rest		7	rest
2	1	60 mins Zone 2	5	1	105 mins Zone 2
	2	rest		2	rest
	3	75 mins Zone 2		3	120 mins Zone 2
	4	rest		4	rest
	5	75 mins Zone 2 & 3		5	120 mins Zone 2
	6	30-45 min Zone 2**		6	45-60 min Zone 2*
	7	rest		7	rest
3	1	75 mins Zone 2	6	1	120 mins Zone 2
	2	rest		2	rest
	3	90 mins Zone 2		3	150 mins Zone 2
	4	rest		4	rest
	5	75 mins Zone 2 & 3		5	150 mins Zone 2
	6	30-45 min Zone 2*		6	45-60 min Zone 2**
	7	rest		7	rest

* = High Cadence	** = Hill Repeats	

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Training: Getting Faster

Building a stronger race-pace & improving FTP

The best way to improve your FTP is a combination of maintaining your base while also adding intervals and tempo rides to improve strength and speed. Intervals refer to short periods of high intensity (Zone 4 & 5) with extended rest periods, while tempo refers to long-ish durations (20-40 minutes) at a challenging intensity (Zone 3 & Zone 4). Hills and sprints are an excellent method to increase strength and improve lactate tolerance, while "maximum distance in 20 minutes" efforts are great at improving speed and prolonging blood-lactate accumulation.

Week	Day	Workout	Week	Day	Workout
1	1	45 mins Zone 3	4	1	90 mins Zone 2
	2	rest		2	rest
	3	3 x 10 min Zone 4***		3	3 x 18 min Zone 4***
	4	rest		4	rest
	5	60 mins Zone 2		5	105 mins Zone 2
	6	30-45 min Zone 2*		6	45-60 min Zone 2**
	7	rest		7	rest
2	1	60 mins Zone 2	5	1	120 mins Zone 2
	2	rest		2	rest
	3	3 x 12 min Zone 4***		3	2 x 20 min Zone 4***
	4	rest		4	rest
	5	75 mins Zone 2 & 3		5	135 mins Zone 2
	6	30-45 min Zone 2*		6	45-60 min Zone 2*
	7	rest		7	rest
3	1	75 mins Zone 2	6	1	120 mins Zone 2
	2	rest		2	rest
	3	3 x 15 min Zone 4***		3	2 x 25 min Zone 4***
	4	rest		4	rest
	5	75-90 mins Zone 2		5	150 mins Zone 2
	6	30-45 min Zone 2*		6	45-60 min Zone 2**
	7	rest		7	rest

* = High Cadence	** = Hill Repeats	*** = Zone 4 Intervals (1:2 ratio Z4:Z2)

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Training: Increasing Maximum Capcacity

Improving your VO2 max

Increasing your VO2 max will occur naturally as a secondary outcome of all other cardiovascular exercise. However, using high intensity intervals (HIIT) workouts can improve VO2 max faster due to the specificity principle. See below for a sample HIIT workout that will improve VO2 max over 8 weeks. Use the HIIT workout structure on the marked HIIT training days. Each training interval should be the hardest intensity you can maintain for the allotted time.

Week	Warm Up (Z1 or Z2)	Interval Duration	Recovery Duration	Repeat	Cooldown (Z1 or Z2)	Total Workout Time
1	10 min	2 min	4 min	2 times	5 min	27 min.
2	10 min	2 min	4 min	3 times	5 min	33 min.
3	10 min	2 min	4 min	4 times	5 min	39 min.
4	10 min	3 min	4 min	2 times	5 min	29 min.
5	10 min	3 min	4 min	3 times	5 min	36 min.
6	10 min	3 min	4 min	4 times	5 min	43 min.
7	10 min	4 min	5 min	3 times	5 min	42 min.
8	10 min	4 min	5 min	4 times	5 min	49 min.

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	Rest	30 mins Zone 2	27 mins HIIT	45 mins Zone 2	Rest	2 x 10 min Zone 4	45 mins Zone 2
2	Rest	40 mins Zone 2	33 mins HIIT	50 mins Zone 2	Rest	20 mins Zone 4	45 mins Zone 2
3	Rest	60 mins Zone 2	39 mins HIIT	60 mins Zone 2	Rest	2 x 20 min Zone 4	45 mins Zone 2
4	Rest	75 mins Zone 2	29 mins HIIT	90 mins Zone 2	Rest	45 mins Zone 4	60 mins Zone 2
5	Rest	60 mins Zone 2	36 mins HIIT	75 mins Zone 2	Rest	60 mins Zone 4	45 mins Zone 2
6	Rest	75 mins Zone 2	43 mins HIIT	90 mins Zone 2	Rest	60 mins Zone 4	45 mins Zone 2
7	Rest	90 mins Zone 2	42 mins HIIT	60 mins Zone 2	Rest	60 mins Zone 4	60 mins Zone 2
8	Rest	75 mins Zone 2	49 mins HIIT	75 mins Zone 2	Rest	60 mins Zone 4	75+ mins Zone 2

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Reference: RPE Scale

RPE Scale		
Scale	Description	Zone
1	Minimal	1
2	Very Easy	1
3	Easy	1/2
4	Moderate	2
5	Challenging	2/3
6	Difficult	3/4
7	Hard	4
8	Very Hard	4/5
9	Extremely Hard	5
10	Maximal Effort	5

You can also use the BORG (1-10) RPE scale to measure the intensity of exercise if you do not have access to a heart rate monitor. Additionally, other physiological varilables can affect heart rate response to exercise on a day-to-day basis as a result of stress, fatigue, exhaustion, illness, and caffiene ingestion. It is important to note that the training zones are not a perfect parallel to HR-based training zones, though they offer a close comparison if necessary.

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Notes

If you have any questions regarding your results, or would like to discuss anything further, please do not hesitate to reach out!

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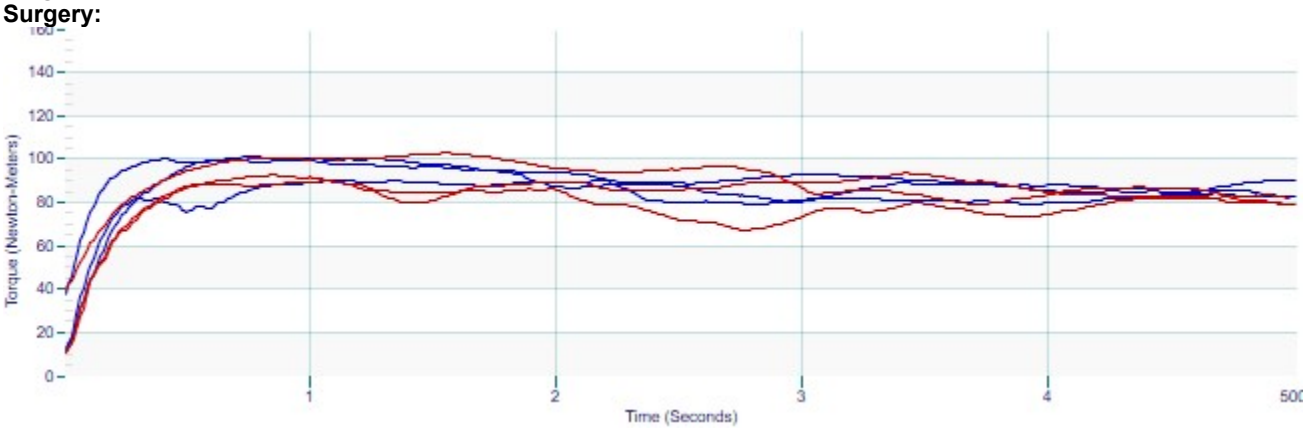
Per Rep Isometric Trq vs. Time - Knee Extension/Flexion

Name: **ID:** **Right/Left:**
Birth date: **Involved Side:** **Group 1:**
Height: **Preferred Side:** **Group 2:**
Weight: **Doctor:**
Gender: **Tester:** Brooke Schultz
Diagnosis:
Surgery:



Right Side Curves Left Side Curves
Isometric Ecc/Con
Angle 70 Degrees 5 Seconds 3 Reps

	Right Flexors (Con)		
Rep	1	2	3
Peak Torque	100	101	90
Average Torque	89	87	85
Peak Torque Slope	79	131	67
Time to Half Peak Torque	0.13	0.04	0.09
Time to Peak Torque	1.25	0.76	1.34
	Left Flexors (Con)		
Rep	1	2	3
Peak Torque	103	93	93
Average Torque	90	79	84
Peak Torque Slope	66	109	27
Time to Half Peak Torque	0.06	0.12	0.11
Time to Peak Torque	1.54	0.84	3.41

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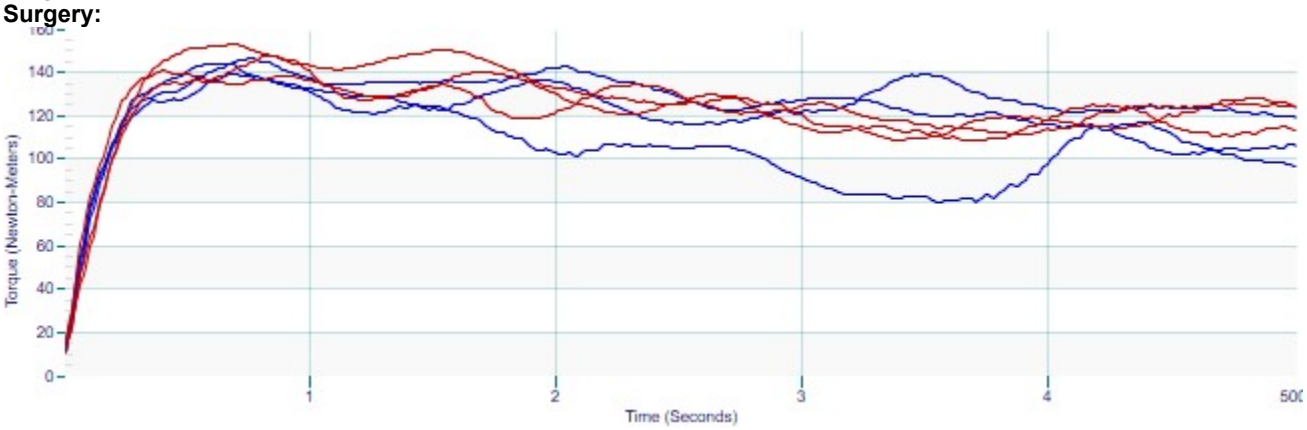
Per Rep Isometric Trq vs. Time - Knee Extension/Flexion

Name: **ID:** **Right/Left:**
Birth date: **Involved Side:** **Group 1:**
Height: **Preferred Side:** **Group 2:**
Weight: **Doctor:**
Gender: **Tester:** Brooke Schultz
Diagnosis:
Surgery:



Right Side Curves Left Side Curves
Isometric Con/Ecc
Angle 70 Degrees 5 Seconds 3 Reps

	Right Extensors (Con)		
Rep	1	2	3
Peak Torque	146	139	144
Average Torque	124	106	125
Peak Torque Slope	193	202	244
Time to Half Peak Torque	0.09	0.09	0.10
Time to Peak Torque	0.75	0.68	0.58
	Left Extensors (Con)		
Rep	1	2	3
Peak Torque	148	141	153
Average Torque	123	122	127
Peak Torque Slope	176	352	219
Time to Half Peak Torque	0.13	0.08	0.14
Time to Peak Torque	0.83	0.39	0.69