Exercise Plan for Diabetic Patients

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Project Background

/ Spring 2021

Family member diagnosed diabetes

/ Summer 2021

Use JMP to conduct Six Sigma DMAIC project

/ Summer 2021

Glucose level greater than 200 mg/dL

/ Fall 2021

Glucose level returned to normal 65-99 mg/dL

Define Phase Project Overview

Voice of Customer (VOC) - family doctor suggested four potential actions to manage diabetes

- Eat healthy meals
- Take Metformin HCl 500 mg
- Take insulin
- **Exercise at a higher heart rate to burn sugar**

Critical to Quality (CTQ)

- Design a treadmill speed walking program
- Reduce blood glucose levels to below 100 mg/dL
- Strengthen lower body muscles and prevent lower body injuries
- Reduce resting heart rate (bpm)

Define Phase Team

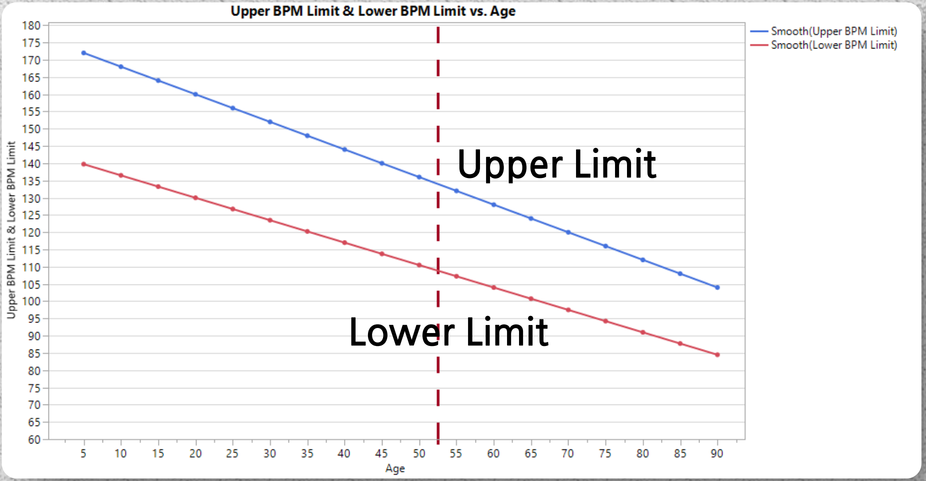
- **Diabetes patient** - checks blood glucose levels daily
- **Family doctor** - checks patient's progress every three months
- **Physical therapist** - helps prevent walking injury
- **Six Sigma advisor** - mentors DMAIC project
- **JMP advisor** - assists with analysis

Measure Phase Exercise Design

- Recommended target heart rate during exercise is **50-85% of maximum heart rate**
- However, calcium score from CT scan is 131, which is at **72nd percentile** for the same age (indicates moderate to high risk of heart attack)
- Consulted with family doctor and decided to set target heart rate at 65-80% range of maximum heart rate to avoid heart attack risk at high heart rate
- Chose brisk walking on treadmill because it offers a wide range of physical benefits, such as weight loss, improved cardiovascular health, lower blood pressure, and lower blood sugar

Measure Phase Maximum Heart Rate

- Maximum heart rate = 220 - age
- **At 52.5 years old, maximum heart rate = 220 - 52.5 = 167.5 bpm**
- Upper bound = 167.5*0.8 = 134 bpm
- Lower bound = 167.5*0.65 = 109 bpm



Measure Phase Heart Attack

- Average resting heart rate is usually between 60-80 bpm
- Exercise strengthens heart muscles and allows it to pump a greater amount of blood with each heartbeat, lowering the resting heart rate and increasing the amount of oxygen in muscles
- **Goal is to also reduce resting heart rate (measured before exercise)**

Analyze Phase Control Variables

Three control variables

- **Walking uphill** - adding inclines requires the heart, lungs, and muscles to work harder
- **HIIT (high-intensity interval training)** - HIIT involves short bursts of vigorous exercise alternated with low-intensity recovery periods
- **Frequency** - American Heart Association recommends 150 minutes of moderate-intensity exercise

Analyze Phase Treadmill Design

- Variables - incline (0 or 5 degrees) and speed (0, 1, 1.5, 2, 2.5, 3, 3.2, 3.4, 3.6 mph)
- Upper speed limit is set at 3.6 mph to avoid going into running mode
- Conduct a full factorial DOE
- Rests between treatment levels to reach resting heart rate

Incline (Degrees)	Speed (MPH)	Heart Rate (BPM)
0	0	92
0	1	94
0	1.5	97
0	2	100
0	2.5	104
0	3	108
0	3.2	112
0	3.4	116
0	3.6	120
5	0	97
5	1	106
5	1.5	115
5	2	117
5	2.5	120
5	3	123
5	3.2	126
5	3.4	132
5	3.6	139

Analyze Phase Fit Model

- R-square for stepwise regression = 97% and ANOVA p-value < 0.05
- Most studentized residuals within +/- 2σ
- Prediction expression includes all factors beside the incline*incline term

Prediction Expression

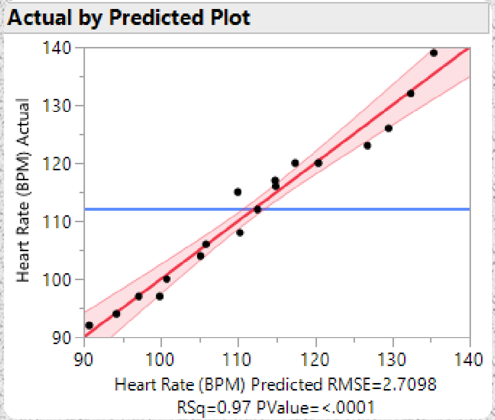
80.42727748

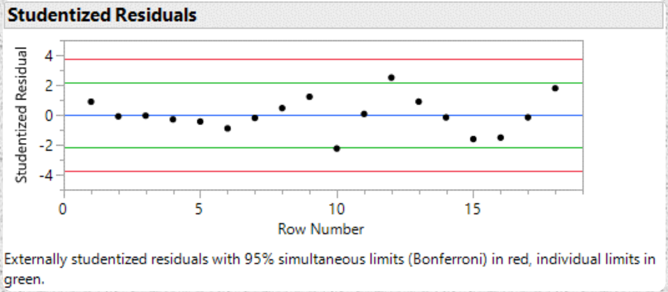
+ 2.9333333333 • Incline (Degrees)

+ 9.9686556109 • Speed (MPH)

+ (Incline (Degrees) − 2.5) • ((Speed (MPH) − 2.2444444444) • 0.4920782852)

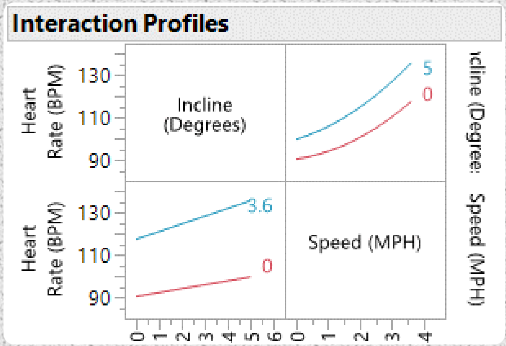
+ (Speed (MPH) − 2.2444444444) • ((Speed (MPH) − 2.2444444444) • 1.4919751545)

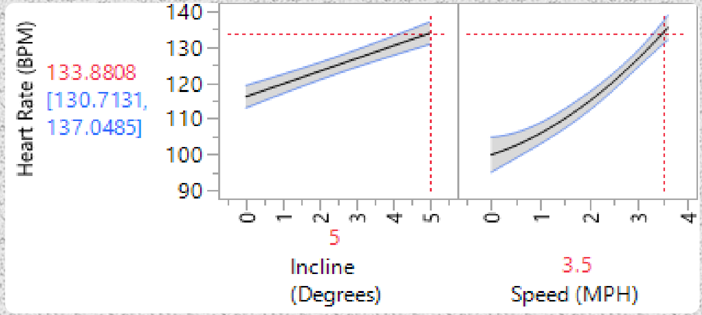


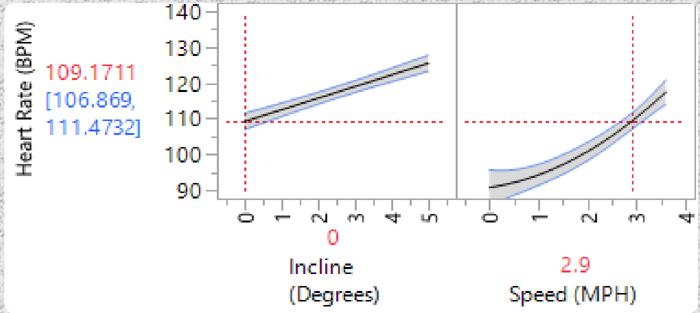


Analyze Phase Interaction Profiler

- Heart rate has a linear relationship with incline (potential energy) and a quadratic one with speed (kinetic energy)
- Upper bound (134 bpm) at incline of 5 degrees and speed of 3.5 mph
- Lower bound (109 bpm) at incline of 0 degrees and speed of 2.9 mph







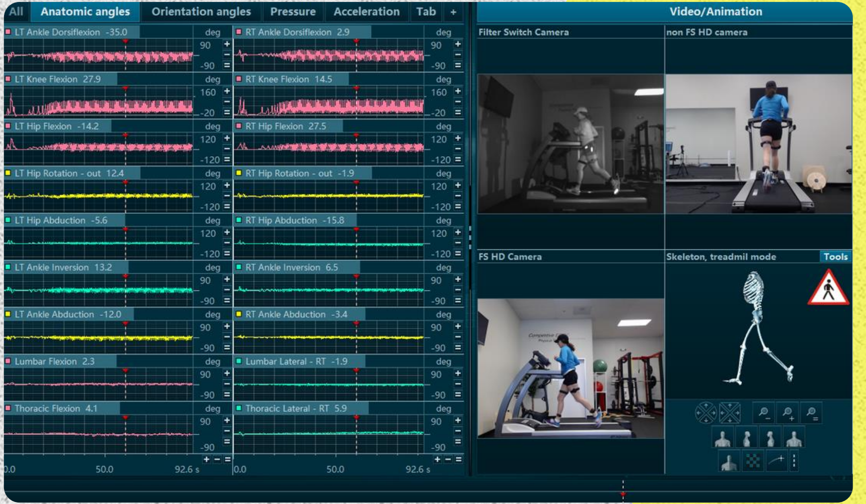
Analyze Phase Injury Risk

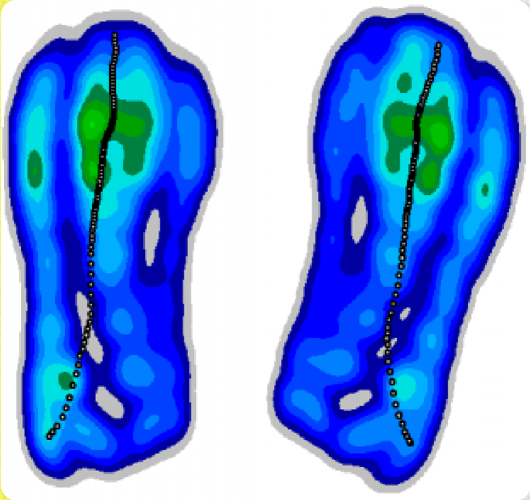
To avoid injury, use the following techniques when walking -

- Keep your head up and look forward
- Relax your neck, shoulders, and back
- Do not slouch or lean forward
- Keep your back straight and engage your abdominal muscles
- Walk with a steady gait, rolling your foot from heel to toe
- Loosely swing your arms

3D Motion Biomechanics

Running Blueprint

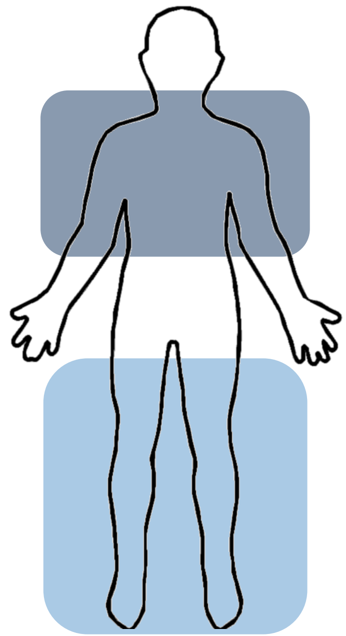


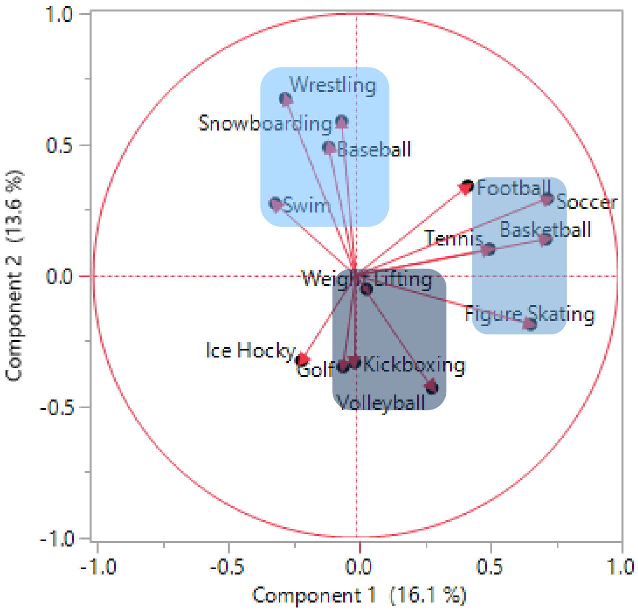


Variable Clustering

Cluster Members

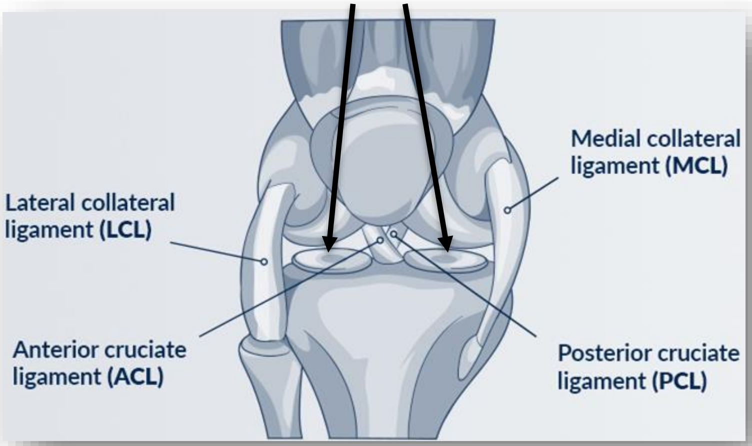
Cluster	Members	RSquare with Own Cluster	RSquare with Next Closest	1-RSquare Ratio
1	Basketball	0.596	0.061	0.43
1	Soccer	0.53	0.158	0.559
1	Tennis	0.262	0.083	0.805
1	Figure Skating	0.596	0.017	0.411
2	Swim	0.514	0.022	0.497
2	Snowboarding	0.398	0.047	0.632
2	Wrestling	0.673	0.02	0.334
3	Volleyball	0.414	0.029	0.603
3	Golf	0.717	0.026	0.29
3	Weight Lifting	0.328	0.003	0.674
4	Football	0.568	0.07	0.465
4	Ice Hocky	0.568	0.069	0.464
5	Baseball	0.584	0.061	0.443
5	Kickboxing	0.584	0.011	0.42





Anterior Cruciate Ligament

Lateral (left) & medial (right) meniscus



The ACL is located at the center of the knee joint from the backside of the thighbone (femur) to the front of the shinbone (tibia).

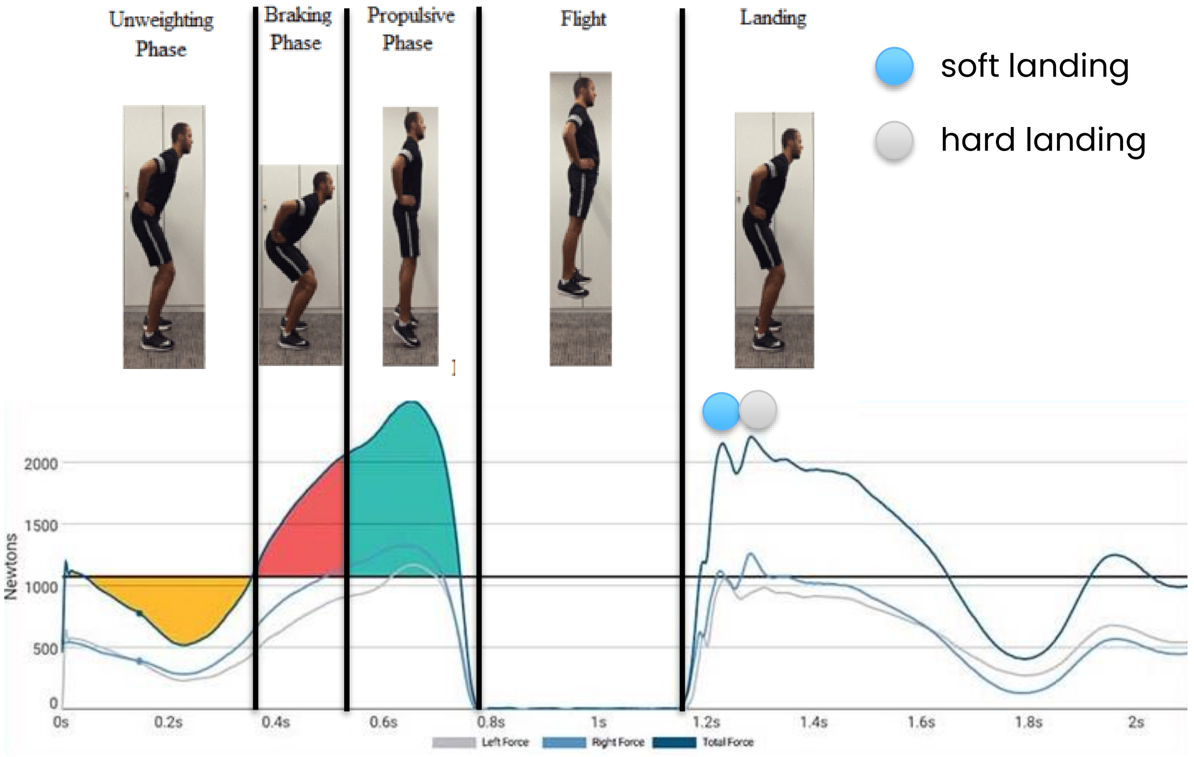
ACL Injury

- **If tibia (shinbone) is moved too far forward or hyperextended, ACL can be torn**
  - Sudden deceleration or pivoting in place
  - Foot is planted and body changes direction rapidly
  - Common sports that are source of ACL tears:
    - **Basketball – jumping, landing, and pivoting**
    - Football – planting foot and rapidly changing direction, body contact
    - Downhill skiing – ski boots higher than calf, moving impact of a fall to knee rather than lower ankle or leg

Countermovement Jump

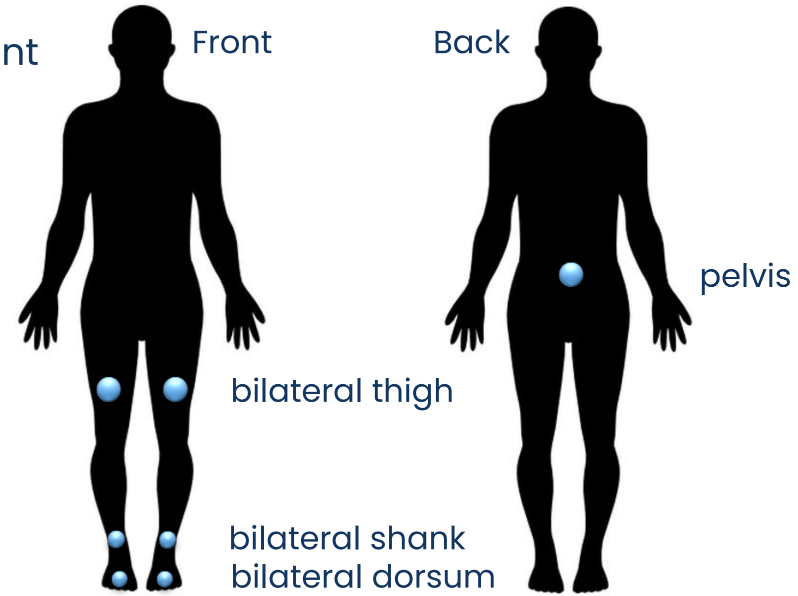
- Assesses the force of the knee to ground (and vice versa)
- Newton's Third Law (again)
- **Too much force from knee to ground means knee experiences just as much force (ACL injury risk)**
- Requires self-coordination between flexion and extension of several body parts (hip, knee, etc.)
- Force and flexion are connected

Countermovement Jump Process



Experimental Design

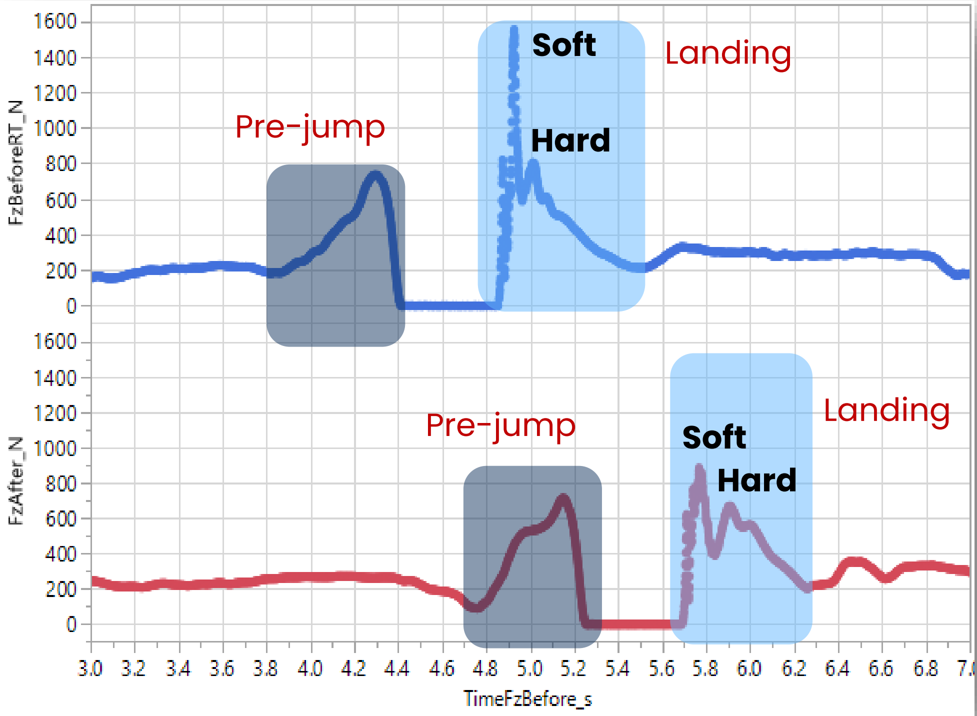
- 7 different sensors were attached to a test subject while he conducted countermovement jump exercise on force plate (before fatigue)
- 1 hour fatigue period – running, squatting, basketball, jumping, cone drills, etc.
- After fatigue, conducted countermovement jump again to study fatigue factor
- Sensor data was transformed through a biomechanical model to simulate the 3D-motion profiles



Individual Force Profile

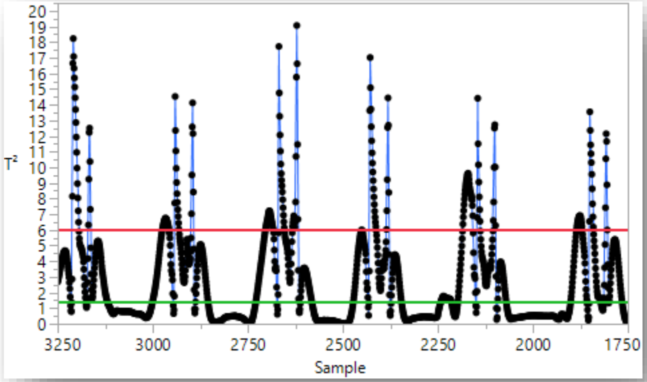
Analyze → Quality and Process → Control Chart Builder (Individual)

- Pre-jump curve (transition from braking to propulsive phase) is smoother for before fatigue
- May indicate that different body parts are well coordinated (and no plateau)
- 2-step (soft and hard) landing mechanism has greater contrast during before fatigue

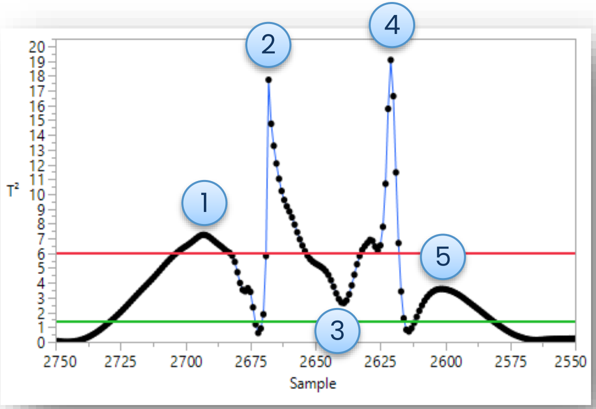


Multivariate Control Chart

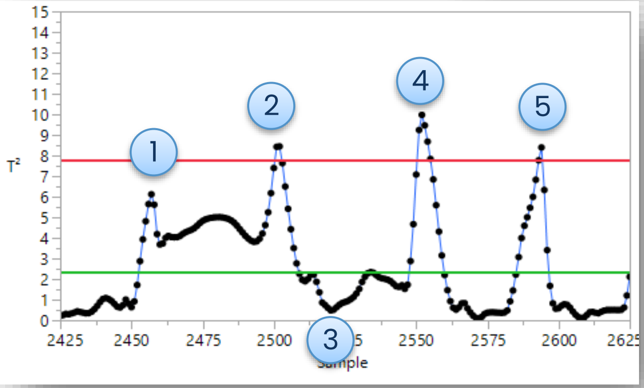
- Multivariate Statistical Process Control Chart studies time domain difference
- More points outside Upper Control Limit for before then after fatigue



Before Fatigue



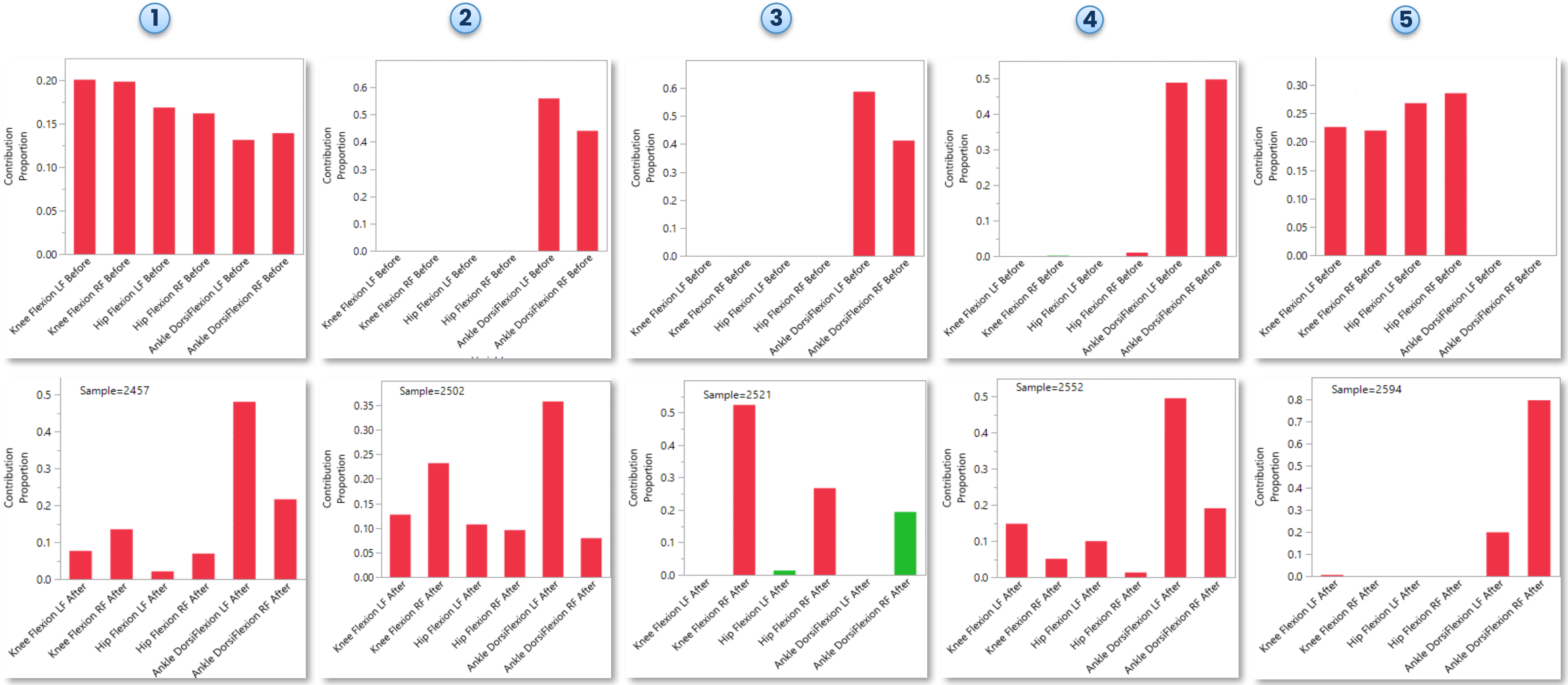
After Fatigue



Analyze → Quality and Process → Model Driven Multivariate Control Chart

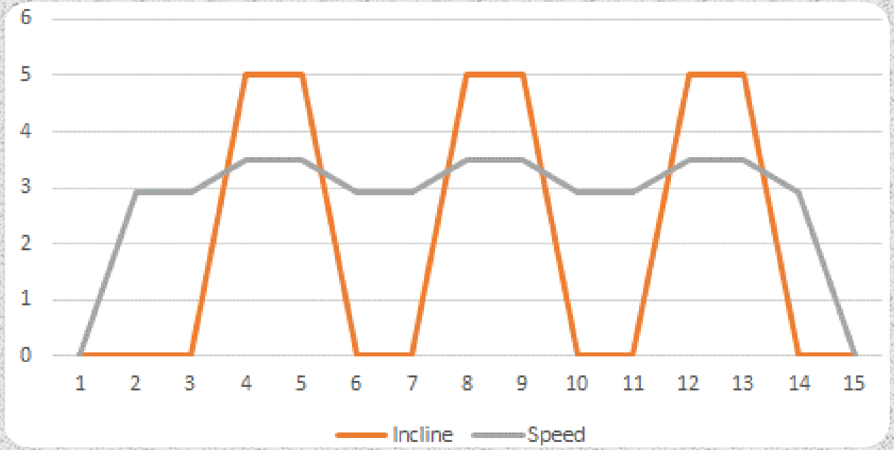
Contribution Comparison

Analyze → Quality and Process → Model Driven Multivariate Control Chart



Improve Phase HIIT Design

- **0-2 minutes** - warmup
- **2-14 minutes** - 3 cycles of 2 minutes at lower limit (109 bpm, 0 degrees, 2.9 mph) and 2 minutes at upper limit (134 bpm, 5 degrees, 3.5 speed)
- **14-15 minutes** - cooldown



Improve Phase Validation Plan

- Measure CT coronary artery calcium score, glucose reading, and resting heart rate after doing the exercise program for three months
- Revise the workout plan (with stronger heart muscles and a lower resting heart rate, the treadmill settings should be changed to meet the bounds of the target heart rate)

Conclusions

- Applied DMAIC Six Sigma framework and JMP 16 platforms to help manage diabetes and lower heart attack risk
- Used Design of Experiment (DOE) to design a treadmill workout plan based on the target heart rate
- Currently completing improve and control phases


THANKS FOR
LISTENING!