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Project Background



Family member diagnosed diabetes



Use JMP to conduct Six Sigma DMAIC project



Glucose level greater than 200 mg/dL



Glucose level returned to normal 65-99 mg/dL

Define Phase <mark>Project Overview</mark>

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 <mark>Exercise Design</mark>

- 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 <mark>Heart Attack</mark>

- 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

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	Incline (Degrees)	Speed (MPH)	Heart Rate (BPM)
	0	0	92
	0	1	94
	0	1.5	97
	0	2	100
15	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
110	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 + 2.933333333 • 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



8.3

Knee Angle

2.2 Tibial Angle

Hip Ankle dist(cm)







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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
- **D** 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 3Dmotion 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



Analyze → Quality and Process → Model Driven Multivariate Control Chart





After Fatigue

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!