Measuring Vibrations on Roller Coasters

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Abstract

Exposure to whole-body vibrations can cause negative health effects, including spinal injuries, neck pain, and even cognitive skill impairments [1] [4]. While there has been research conducted to explore how whole-body vibrations felt in automobiles and heavy machinery affect human health, there is not much information on the whole-body vibrations experienced on roller coasters, particularly with respect to the riders position on the coaster train. This proposal suggests building a device using an Arduino microcontroller and an accelerometer-gyroscope (GY-521) that will measure the vibrations felt on different roller coasters and output data that represents the vibrations versus time relationship on different parts of a roller coaster train. This will be used to determine if the encountered vibrations are safe for the long-term health of riders and if sitting in different parts of a roller coaster train affects the level of vibrations felt and the overall safety of the rider.

Introduction

Every day, humans experience many different types of movement and motion. Anything from sitting in a car to walking around the house to riding a roller coaster exposes our bodies to external forces. Amusement parks are generally associated with thrill and enjoyment; however, these places of excitement might actually be leaving customers with negative, long-term health effects. During a roller coaster ride, people are exposed to a variety of forces, each acting on and affecting our bodies in different ways [1]. Our bodies are jerked from side to side and up and down throughout the duration of a roller coaster ride, leading to possible brain and neck injuries. They are also subjected to a great amount of whole-body vibrations. A vibration is the motion of a body about an equilibrium position; any sudden changes in forces can excite vibrations [1]. The whole-body vibrations induced in roller coasters could be potentially dangerous for the long-term health of riders, resulting in chronic neck or back pain [2]. However, the magnitude of these forces may vary based on the location of the rider on the roller coaster train. Therefore, I ask the questions: Are the vibrations felt on roller coasters safe for the long-term health of riders? And, does sitting on different parts of roller coasters affect the level of vibrations felt and overall safety of the rider?

Background

Our bodies experience a number of forces during a roller coaster ride; they are an integral part of the roller coaster experience. These forces, usually expressed in terms of a G force, must fall between -6 and 6 G's: too much G force and the ride is dangerous, but too little G force and the ride is boring [1]. There is a fine line between what is thrilling (but safe) and what is dangerous when it comes to determining the level of forces that should be present on a roller

coaster. Although there is a certification process for roller coasters, this line may become blurred, leading to the possible injury of riders [3]. One study focused on how roller coasters may induce head injuries in riders. This study collected head kinematics data from roller coaster rides and compared it to everyday activities and soccer headers and found that average brain displacements and strain levels experienced on roller coasters were comparable with those in mild sports impacts. This reveals a hidden danger that people risk when they ride roller coasters; however, this study did not focus specifically on how vibrations can affect the human body.

In general, riders experience whole-body vibrations transmitted into their bodies from the roller coaster train, but there is a lack of information on how vibrations affect human health, especially on roller coasters. Vibrations are generally disliked and can cause numerous biomechanical effects on the body, including motion sickness and negative effects on cognitive skills [1]. Not only this, but prolonged exposure to whole-body vibrations can lead to spinal disorders and lower back pain [4]. Of course, health risks due to whole-body vibrations depend on the level of vibration (frequency), how often people are exposed to whole-body vibrations, how long they are exposed, and other ergonomic factors [5]. Many of the studies that research whole-body vibrations investigate whole-body vibrations experienced in automobiles such as semi-trucks or heavy machinery. It can be assumed that people who operate these automobiles are at a higher risk of experiencing negative health effects from vibrations because of how often they are exposed to them. However, because most people do not go on roller coasters too often, and because there is not much research on the vibrations experienced on roller coasters, it is difficult to predict how those vibrations may influence the long-term health of riders. It is also because of this lack of research that it is unknown how much (if at all) the level of vibration differs between seats on a roller coaster train. This is why I seek to discover if sitting on different

parts of a roller coaster affects the level of vibrations felt and if these vibrations are safe for the long-term health of riders.

Methods

I propose a four-day trip to Six Flags Magic Mountain in Valencia, California, where I can measure the vibrations felt on four sit-down, steel roller coasters: Goliath, Viper, The New Revolution, and Full Throttle. To do this, I will build a device using an Arduino microcontroller and an accelerometer-gyroscope (GY-521) that will sample and record the vibrations felt on a roller coaster ride every second. The accelerometer-gyroscope will connect directly to the Arduino UNO device. An LCD screen will be used to display values and a keypad to input certain values, such as which coaster I'm riding and what row I am in. I will spend time developing the software for the device to run smoothly; then, I will take this device with me on the different roller coasters (focusing on one roller coaster each day) to measure vibration data from each row of each roller coaster train; therefore, I will need to ride each roller coaster multiple times to get vibration data from multiple rows of the train. Because each row of the train has two seats, I will sit on the same side for each roller coaster to be consistent and achieve more accurate results. The collected data will then be plotted in a frequency versus time graph to visually represent the level of vibration felt throughout the duration of the roller coaster ride. Lastly, I will analyze the data to discover how the level of vibration differs on different seats of a roller coaster, and I will compare the vibration data to the range of human vibration tolerance to determine if the roller coasters are safe for riders.

Expected Results

When conducted, this research will produce data that represents the vibrations felt on different parts of roller coaster trains throughout the duration of a ride. The vibration-measuring device will generate frequency versus time graphs with the data that it collects (vibration frequency per second) which I will use to discover how the level of vibration differs on different seats of a roller coaster train and how the data compares to the range of human vibration tolerances and resonance frequencies. Because roller coasters go through a very rigorous certification process, I expect to see vibrations within the range of healthy human tolerances. I also expect to see higher levels of vibrations felt on seats that are directly above the wheel of the roller coaster train.

Conclusion

There may be a hidden danger and risk associated with riding roller coasters. During a roller coaster ride, people experience many different movements, jerks, forces, and vibrations, each having a different effect on the body. My research will focus specifically on how the vibrations felt on roller coasters may affect the long term health of riders and whether or not sitting in different parts of roller coasters affects the level of vibrations felt and the safety of the rider. While there are some studies which focus on velocity, acceleration, jerk, snap, and higher order derivatives of forces felt on roller coasters and other studies which focus on the displacement of the brain during roller coaster rides, there is a scarcity of studies that focus on the vibrations felt on roller coasters, so there is a lack of understanding of how these vibrations may affect human health. Because whole-body vibrations can cause negative, long-term health

problems, it is important to understand the level of vibrations that people may experience on a roller coaster when considering the safety and health of riders.

References

[1] A.-M. Pendrill and D. Eager, “Velocity, acceleration, jerk, snap and vibration: Forces in our bodies during a roller coaster ride,” *Physics Education*, vol. 55, no. 6, p. 065012, 2020.

[2] L. C. Gant, D. G. Wilder, and D. E. Wasserman, “Human response to single and combined sinusoidal vertical vibration — revisited,” *Journal of Low Frequency Noise, Vibration and Active Control*, vol. 31, no. 1, pp. 21–28, 2012.

[3] C. Kuo, L. C. Wu, P. P. Ye, K. Laksari, D. B. Camarillo, and E. Kuhl, “Pilot findings of brain displacements and deformations during roller coaster rides,” *Journal of Neurotrauma*, vol. 34, no. 22, pp. 3198–3205, 2017.

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[5] E. Johanning, “Diagnosis of whole-body vibration related health problems in Occupational Medicine,” *Journal of Low Frequency Noise, Vibration and Active Control*, vol. 30, no. 3, pp. 207–220, 2011.

Timeline

Week 1-2: Preparation

- Build the vibration sensing device and write the code to get it working properly.

Week 3: Conducting the study

- Spend a day at Six Flags collecting data on Goliath.

Week 4: Conducting the study

- Spend a day at Six Flags collecting data on Viper.

Week 5: Conducting the study

- Spend a day at Six Flags collecting data on The New Revolution.

Week 6: Conducting the study

- Spend a day at Six Flags collecting data on Full Throttle.

Week 7-8: Analysis

- Analysis of data and interpretation of results.
- Write the final research paper.

Budget

Expense	Cost	Quantity	Subtotal
Six Flags Magic Mountain season pass	$98.98	1	$98.98
LAVFIN Arduino UNO Super Starter Kit	$27.99 + $4.49 shipping	1	$32.48
Accelerometer-gyroscope (GY-521)	$6.00	1	$6.00
Travel from LMU to Six Flags and back	77 mi X (1gal/25mi) X ($4.89/gal) = $15.06	4 trips	$60.24
Meal in the park	$15 X 2 meals = $30	4 trips	$120.00
Total	**----------**	**----------**	**$317.70**