Individual Analytical Analyses II

18F17 - Smart Helmet

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ME 486C- Spring 2019

Design4Practice (D4P) Program

To: Dr. Trevas

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Re: Individual Analytical Analysis II

This assignment is due 3/01/19

Introduction

A contemporary issue in athletic sports are injuries, specifically head injuries. Contact to contact sports such as American football is one of the highest head related injuries in any sports. The analytical analysis that will be researched is the angular acceleration of the head when impacted. One might expect the linear acceleration is the main cause of brain injuries, but it is the angular acceleration [1]. A comparison of linear and angular acceleration will be assessed. On an Excel spreadsheet, the various times to determine the acceleration at impact will help see the different accelerations at certain times. Both accelerations will be plotted to determine a relationship.

Assumptions

This will be taking the speed of the player that is about 25 mph [2] and converting to meters per second, v = 10.3 m/s.

The assumption made is the time a player contacts another player; the time will vary due to the lack of information provided. The time will vary from 1s – 0.01s because a player stops abruptly. This can determine the amount of G-forces a player takes in the various amounts of time to come to a complete stop.

The new assumptions that is made is the circumference of a human head. The average male circumference is about 60 centimeters [3]. Convert circumference into radius can be seen in equation (5) which the radius of a head is about 9.07 cm.

An educational assumption of how much a helmet will add to the total circumference of a head will be about three inches and converting to centimeters is 7.62 cm.

The angular acceleration in units is radians per second squared (rad/s^2) therefore angular acceleration is a dimensionless variable. From this, a possible relationship between angular acceleration and g-force can be modeled.

Equations

The equations used are to determine the angular acceleration and find a relationship between angular and linear acceleration.

The acceleration equation can be seen in (1) and is represented as *a*. The Δv represents the difference in velocity and Δt is the time.

$$a = \frac{\Delta v}{\Delta t} \tag{1}$$

The angular acceleration equation can be seen in (2) and is represented as α. The ω_2 represents final angular velocity of the player and ω_1 is the initial angular velocity, which is zero because the player is not moving, and t is the time. The angular acceleration of the player will determine the G-force created.

$$\alpha = \frac{\Delta \omega}{\Delta t} \tag{2}$$

The angular velocity in equation (3) which is represented as *ω*. The *v* is the linear velocity of the circular path. The *r* represents the radius of the object, which is the head.

$$\omega = \frac{v}{r} \tag{3}$$

Changing the order of equation (3) to have the velocity can be seen in equation (4).

$$v = \omega r \tag{4}$$

Combining equations (1) and (4) by substituting the velocity in equation (4) into (1) will yield the tangential acceleration a_t in equation (5).

$$a_t = \frac{r\Delta\omega}{\Delta t} \tag{5}$$

Setting equations (5) and (2) equal to one another and solving for angular acceleration, a new representation of angular acceleration can be given in equation (6).

$$\alpha = \frac{a_t}{r} \tag{6}$$

The amount of G-force that is created is equal to the acceleration of gravity which is 9.81 m/s^2, the relationship between G-force and angular acceleration can be defined in equation (7). The various times on impact will allow the team to see the G-forces at certain times and give more information on when the impact can be fatal.

$$G = \frac{\alpha}{9.81} \tag{7}$$

Results

The comparative results can be seen in Appendix A, where the angular acceleration has a greater value. This shows that the rotational motion of the head has a greater angular acceleration rather than linear. As the time decreases, the acceleration of linear and angular both increase but angular increase dramatically. When comparing the results of g-forces in Appendix B, there are similar results from Appendix A. Both follow the same trend and shows that angular acceleration produces a larger g-force. When a player makes a tackle and is stopped in less than 0.2 seconds than the chance of a concussion is greater. The purpose of the team is to prevent brain injuries in an individual, to do this, the team needs to focus on angular acceleration. The calculations do not account for the padding inside due to the complexity of designs that will allow the helmet to absorb greater impacts. Also, there is more to think of when an impact occurs such as the muscles each individual has in their necks; the stronger the muscles, the more impact the individual can take. These are not part of the assumptions due the various data there is but the data that was analyzed gives the team a new problem to solve. The results of the angular and linear acceleration show the angular acceleration does have more of an effect on a person's head than linear acceleration. Therefore, the team should focus on a gyroscope sensor based on the data provided below. Originally, the focus was on linear acceleration because the team thought the angular acceleration could be neglected due to how small the head rotates. Based on the calculations that was done, angular acceleration is a necessity.

Appendix A:

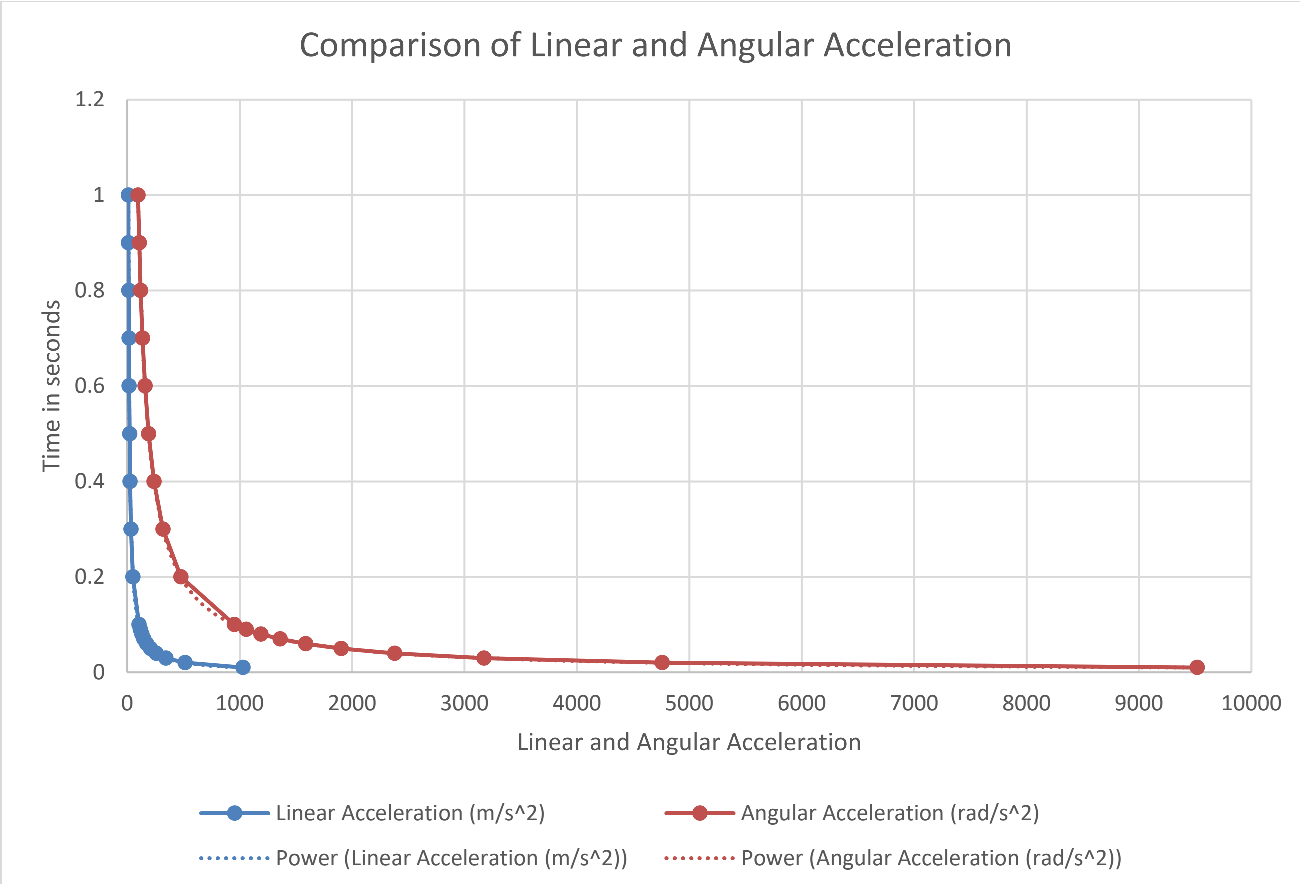

Figure A: Comparison of Linear and Angular Acceleration

Appendix B:

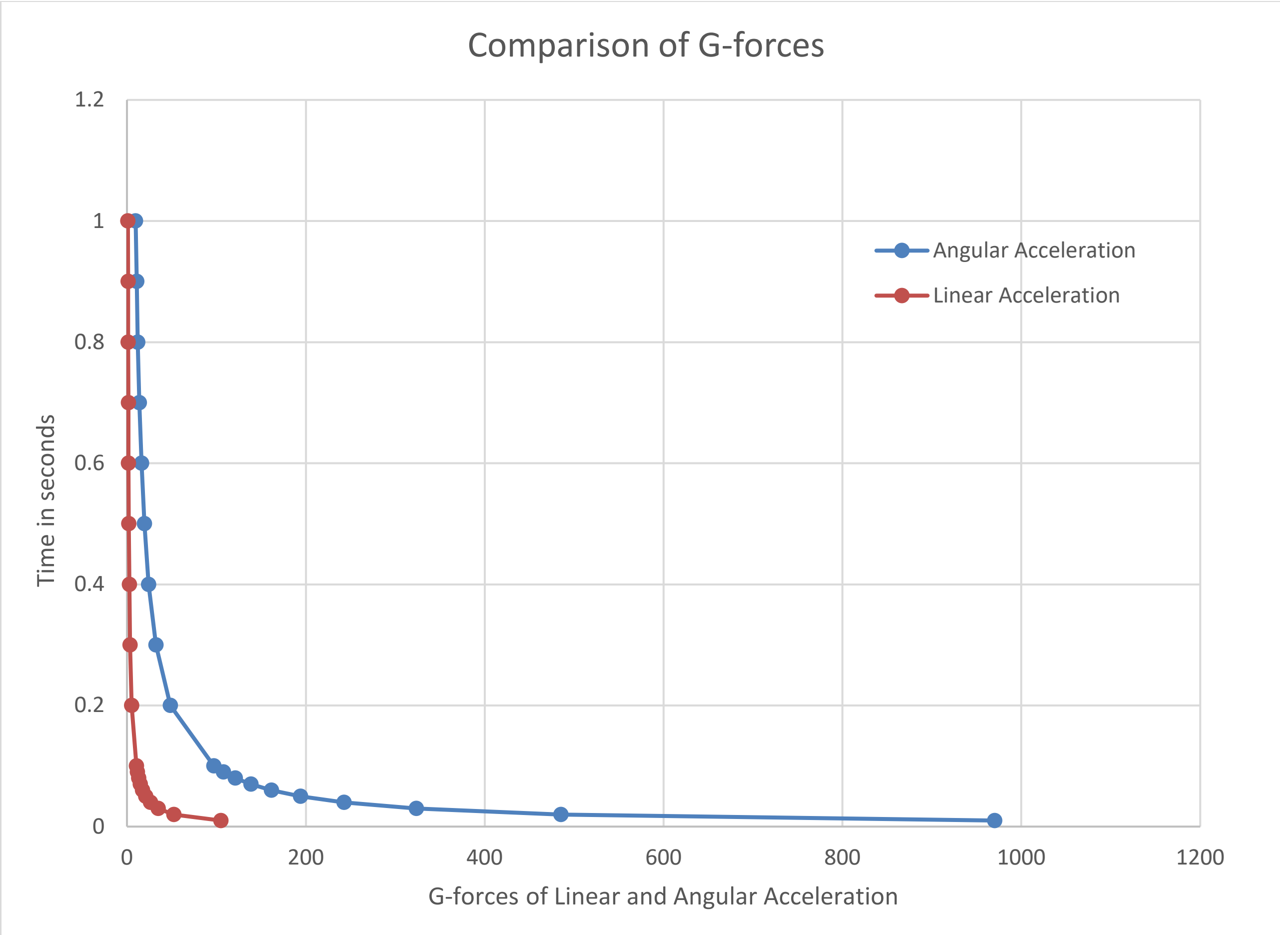

Figure B: Comparison of G-forces

Reference

[1] A. I. King, K. H. Yang, L. Zhang, and W. Hardy, "IS HEAD INJURY CAUSED BY LINEAR OR ANGULAR ACCELERATION?" pp. 1–12, Sep. 2003.

[2] M. Bowen, "Ranking the NFL's fastest players," ESPN, 08-Jun-2017. [Online]. Available: http://www.espn.com/nfl/story/_/id/19520414/ranking-nfl-fastest-players-2017. [Accessed: 08-Nov-2018].

[3] "What Is the Average Size of the Human Head?," *Reference*. [Online]. Available: https://www.reference.com/science/average-size-human-head-62364d028e431bf3. [Accessed: 28-Feb-2019].